

HOW COMMON IS WORKPLACE TRANSFORMATION AND WHO ADOPTS IT?

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The author, using data on 694 U.S. manufacturing establishments from a 1992 survey, examines the incidence of innovative work practices (teams, job rotation, quality circles, and Total Quality Management) and investigates what variables, including human resource practices, are associated with the adoption of these practices. He finds that about 35% of private sector establishments with 50 or more employees made substantial use of flexible work organization in 1992. Some factors associated with an establishment's adoption of these practices are being in an internationally competitive product market, having a technology that requires high levels of skill, following a "high road" strategy that emphasizes variety, service, and quality rather than low cost, and using such human resource practices as high levels of training and innovative pay systems.

A new conventional wisdom has emerged concerning work organization in the United States. This view holds that gains in productivity depend on adopting new models of work organization, models that entail internal labor market (ILM) innovations such as broad job definitions and the use of teams, employee problem solving groups, and quality circles. Scholars have used a variety of labels to describe these systems—among them, "transformed" systems, "salaried" systems, "flexible specialization," "high commitment" organization, and "high performance work organization." Influential national reports such as *Made in America* (Dertouzos, Lester, and Solow 1989) and the

Cuomo Commission Report (1988) have emphasized the importance of spreading flexible work organization throughout the economy. Many American firms have begun this transformation, while others have either chosen not to make the shift or have been unable to do so. A common policy prescription is for the state, local, and federal governments to intervene with training or incentives to adopt new work systems.

Running through this academic and policy discussion have been two major unresolved questions. First, how many firms are engaged in reorganizing work? And second, what differentiates firms that undertake these efforts from those that do not?

With respect to the first question, one widely cited national estimate comes from the Commission on the Skills of the

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The survey employed in this paper will be made publicly available beginning September 1995.

American Workforce, which claimed that 5% of employers are so-called High Performance Work Organizations (1990). The Commission, however, has never described clearly the source of this estimate. A national survey of Fortune 1000 firms by Lawler, Mohrman, and Ledford (1992) examined quality programs, and a survey by Delaney, Lewin, and Ichniowski (1989) examined ILM rules more generally; below, I compare the results of those efforts with findings of this paper. For specific industries, Milkman (1991) provided estimates for Japanese electronics plants in California, Florida and Kenny (1991) studied auto parts suppliers in the Midwest, and Kelley (1989) and Keefe (1991) examined manufacturing sites using machine tools.

On the second question, systematic studies of the determinants of adoption are extremely sparse. That is, there is little or no research that takes work organization as the dependent variable and tests hypotheses found in the literature. Adequate data have not hitherto been available to take the discussion very much beyond anecdotal evidence.

In this paper I employ a survey I conducted in 1992 to provide a description of ILM practices across a representative range of American industries. Some important advantages of this survey over previously available data sources are its coverage of a wide range of American employers (all private sector establishments with 50 or more employees), the fact that it was conducted at the establishment level rather than the corporate headquarters level, and its very high response rate (65.5%). My analysis addresses both questions mentioned above, providing evidence on the distribution of new forms of work organization among American workplaces nationwide, and explaining the pattern of diffusion of these new forms of organization by estimating models that contain variables representing a number of competing hypotheses.

The Survey

The survey upon which this paper is based contains 875 observations on American establishments and was conducted in 1992.¹ An

¹After the elimination of cases with missing variables and a few establishments that slipped into the

establishment is defined as a business address and is distinct from a company. For example, each assembly plant of General Motors is an establishment, as is the corner gas station. The great advantage of surveying establishments, as opposed to firms, is that the respondent in an establishment (of whom more will be said below) is likely to know the facts. I wanted to avoid the risks inherent in surveys that rely on reports of corporate human resource personnel about practices in branch plants on the other side of the country.

The sampling universe was the Dun and Bradstreet establishment file, which purports to be a list of all establishments in the nation.² In a comparison of this file with alternative sampling frames (the unemployment insurance files, the telephone white pages, direct enumeration, and Chamber of Commerce membership listings), Kalleberg, Marsden, Aldrich, and Cassell (1990) found that for a local area the Dun and Bradstreet file and the unemployment insurance files yield representative samples and are generally the best available sources. For creating a national sample, the Dun and Bradstreet file is the only practical choice.

Considerable thought went into the selection of respondents. Although in many cases a human resources person might be appropriate, automatic selection of people in this position was avoided. Years of open-ended interviews with firms suggested to me that too often HRM staff, even at the establishment level, are not in touch with work organization. Therefore, the introductory letter said:

In order to get the best possible answers we need the cooperation of the most senior person at your location in charge of production of goods and services. For example, in manufacturing this might be the plant manager. In a non-manufacturing setting it might be the head of the office or the manager responsible for operations.

The survey research firm worked with the

survey inappropriately, the final sample size used in this paper is 694.

²This commercial file is publicly available, for a fee, from Dun and Bradstreet.

establishment to identify the most knowledgeable respondent.³

The sample was limited to establishments with 50 or more employees in non-agricultural industries.⁴ Non-profit organizations were eliminated. The sample was size-stratified in order to create adequate samples within size categories, and appropriate weights are used to create a representative sample of establishments. Each contact was preceded by an introductory letter and a worksheet, and the interviews were conducted by telephone. The response rate was 65.5%.⁵

A final point regarding the survey procedure concerns the unit of analysis within the establishment. Many variables were collected for the entire establishment. Detailed information on work organization, however, was obtained only for CORE employees. The reason for that restriction is that no single answer regarding, say, job training is likely to be applicable to all occupational groups within an establishment, since employers have distinctive ILM systems for different families of jobs (Osterman 1987). Because it was not practical to collect ILM data on all job families, the notion of a CORE job was developed. The CORE job was defined as

the largest group of non-supervisory, non-managerial workers at this location who are directly

Table 1. The Distribution of CORE Occupations.

Occupation	Percent
Professional/Technical	14.3%
Sales	19.0
Clerical	6.0
Service	18.3
Blue-Collar	42.3

involved in making the product or in providing the service at your location. We want you to think of the various groups directly involved in making the product or providing the service and then focus on the largest group. For example, these might be assembly-line workers at a factory or computer programmers in a software company, or sales or service representatives in an insurance company.

Table I shows the distribution of the CORE job by broad occupational categories. (The CORE jobs were coded as two-digit occupations. This table represents a further collapsing of these categories.) It is apparent, and indeed a strength of the survey, that there is considerable variation. It will be important in the analysis that follows to control for occupation.⁶

It is possible to estimate response rate bias by using variables in the Dun and Bradstreet file. I estimated a logit model in which the dependent variable was the probability of response and the independent variables were size, a dummy equal to one if the establishment was manufacturing, a dummy equal to one if the establishment was a headquarters of a multi-branch firm, and a dummy equal to one if the establishment was not part of a larger enterprise. The manufacturing dummy and the headquarters dummy were significant. Transforming the coefficient at the mean value of the variables indicated that the probability of response increased by 5 percentage points if the respondent was in manufacturing. A similar calculation revealed that the probability of response decreased by 8 percentage points if the establishment was a headquarters. Even among non-manufacturing headquarters establishments, however, the response rate in the survey was 59.1%. The weights used in this paper are adjusted to reflect non-response.

⁶The distribution of CORE jobs by industry follows the pattern one would expect. For example, in manufacturing, firms blue-collar jobs were designated as the CORE job in 86.3% of the cases. In Finance, Insurance, and Real Estate the distribution of CORE jobs was 7.3% professional, 54.1% sales, 20.4% clerical, 18.0% service, and 0% blue-collar.

³46.0% of the respondents worked in a human resources function and 54.0% were line managers. I entered a dummy variable for HRM work in the equations reported below, and this variable was insignificant, indicating that the answers did not systematically vary with the respondent's position. Recall that the sampling unit is the establishment, not the firm.

⁴According to the Dun and Bradstreet file, establishments with 50 or more employees represent just 10% of all establishments. According to the May 1988 Current Population Survey, however, they represent 51% of all employees.

⁵The survey was conducted by the University of Massachusetts Center for Survey Research. The Delaney, Lewin, and Ichniowski survey, which contained a very detailed and rich set of questions about a wide range of work practices, had a response rate of 6.5%. Lawler, Mohrman, and Ledford had a response rate of 32%. That survey was limited to the 1,000 largest firms, and it was answered by a respondent in corporate headquarters with regard to practices for all employees in the entire company.

Flexible Work Organization

In order to describe and analyze the distribution of more flexible work systems, we must define and operationalize the idea. The problem is that there is no single accepted definition. Although it seems fair to say that the many scholars who have written on the topic have the same broad set of practices in mind, different authors place primary emphasis on somewhat different sets of dimensions of those practices.

The difficulty of developing an unambiguous definition is exacerbated by the fact that firms that we might all agree are examples of flexible work organization nonetheless exhibit somewhat different practices. For example, one model is the self-directed work teams implemented in sites such as Corning and Cummins Engine and in white-collar settings such as Hanover Insurance. On the other hand, although the General Motors NUMMI plant has created teams and has numerous opportunities for employee involvement in quality, the actual work tasks are rigidly prescribed (Adler 1992; Brown, Reich, and Stern 1991). It is also the case that some elements of flexible work organization, such as employee involvement and problem solving, have been incorporated—albeit with a different vocabulary—in the newly emergent quality movement.

My strategy will be to develop various measures of establishment practice. I will not insist that any single particular practice is necessary for an establishment to be classified as "flexible"; instead, I will look for a mix of several practices. Second, other aspects of ILM rules—regarding wages, employment security, and so forth—will be treated as supporting HRM practices that are, as a hypothesis, necessary for the successful implementation of flexible work organization. The correlation between these supporting rules and flexible work organization will be examined below.

It is also important to note that although many of the examples and the language describing flexible work systems are drawn from manufacturing, the concept itself is widely applicable. The survey included the complete range of American industries, and they

will be included in the analysis. At various points, however, I will distinguish between manufacturing and non-manufacturing.

Work Organization

In this section I examine the distribution and penetration of the work organization practices. The range of actual practices suggests that no single measure or question is likely to be appropriate in all firms. Therefore, the survey asked about four practices (all with respect to the CORE job family): self-directed work teams, job rotation, employee problem-solving groups (or quality circles), and Total Quality Management. Respondents were asked whether each practice was employed in the establishment and, if the answer was yes, what percentage of CORE employees was involved. The precise definitions given for each practice are shown in Appendix A.⁷

Table 2 shows the distribution of each practice for two levels of penetration: whether the practice is used at all, and whether at least 50% of CORE employees are involved.

It is clear that if the relevant criterion is whether a given practice is used among *any* CORE employees, we must conclude that the elements of flexible work are quite widespread. For example, over half of the establishments use teams, and 33.5% employ TQM. The picture changes, however, when we look only at flexible work organization practices in which at least 50% of the employees are involved: the occurrence of each practice then falls by roughly 15 percentage points.⁸ Even so, the distribution of self-directed work

⁷As several people have pointed out, the survey did not directly observe the actual work practices. Respondents may tend to exaggerate, in the direction of socially acceptable responses, their actual practices. As already noted, however, considerable care was taken to work with the most knowledgeable available respondent. Furthermore, as the statistical results below demonstrate, the responses are not simply noise; they are correlated in sensible ways with explanatory variables. Nonetheless, as is true in all surveys of this kind, the point estimates of the practices should be treated with caution.

⁸The results of Lawler, Mohrman, and Ledford are broadly consistent with mine. They find that 66% of the

Table 2. The Extent of Use of Innovative Work Practices, as Indicated by Two Measures of Penetration.

Type	Percentage at Any Percent Level of Penetration		Percentage at 50% or Higher Level of Penetration	
	All	Manufacturing	All	Manufacturing
Teams	54.5%	50.1%	40.5%	32.3%
Rotation	43.4	55.6	26.6	37.4
TQM	33.5	44.9	24.5	32.1
QC	40.8	45.6	27.4	29.7
None	21.8	16.0	36.0	33.2

teams is surprisingly widespread. There is clearly much higher use of this practice than of the others.

In the manufacturing/blue-collar sample, as in the total sample, there appears to be substantial diffusion of flexible work practices if we examine the use of those practices at any level, and a substantial drop-off in diffusion if we look only at instances in which at least 50% of CORE workers participate. Self-directed teams appear less widespread in manufacturing than elsewhere in the economy,⁹ but the other practices are more common in manufacturing.

These data lead to the natural question of whether the practices form groups from which emerge identifiable patterns that might be thought of as the new systems discussed in the literature. Table 3 shows how the practices cluster together when the 50% participation threshold is used. (Note, however, that no conclusions are changed when other thresholds are imposed.) It appears that there is no single major dominant cluster of practices. Each of the possible combinations is represented, and in most of the cases the distribution of clusters seems rather even.

Fortune 1000 firms in their sample have quality circles and that 47% have self-managed work teams. In both cases the modal degree of penetration is below 20% for those firms that do have the practice (Lawler, Mohrman, and Ledford 1992:20–22).

⁹An explanation for this pattern suggested by Jan Klein (1991) is that self-managed work teams place strains on the inventory management system in manufacturing.

This conclusion changes a bit when one looks for what might be termed an "anchoring practice." Among non-manufacturing establishments in which the CORE employees were not blue-collar, 71.7% of those establishments that engaged in at least one practice had self-managed teams. Even here, however, nearly 30% engaged in some combination of practices that did not involve teams. By contrast, there is no evidence of an anchoring practice among blue-collar CORE employees in manufacturing. Job rotation comes closest: among those establishments that engaged in at least one flexible work practice, 56.3% used job rotation and 43.7%

Table 3. Clustering of Work Practices. (50% or Greater Penetration)

Description	Entire Sample	Manufacturing/ Blue-Collar
None	36.0%	33.2%
All	4.8	5.0
Teams Only	14.4	5.5
Rotation Only	7.0	11.7
QC Only	3.1	2.4
TQM Only	2.6	4.5
Team/Rotation	4.8	4.6
Team/QC	4.3	3.3
Team/TQM	4.6	4.2
Rotation/QC	3.0	3.3
Rotation/TQM	1.5	4.5
TQM/QC	4.4	4.9
Team/TQM/QC	3.6	4.2
Team/Rotation/TQM	1.2	1.6
Team/Rotation/QC	2.3	3.4
Rotation/TQM/QC	1.4	2.9

had some combination that did not involve job rotation.¹⁰

A final question, which is virtually imposed by the popular discussion, is whether it is possible to provide a summary figure regarding the use of High Performance Work Systems. The numerous definitions in the scholarly literature might lead one to suspect that this is a difficult question to answer, and nothing in these data suggest otherwise. As already noted, there is no dominant pattern.

If we are pushed to state a definition, it might be reasonable to characterize an organization as "transformed" if there are at least two practices in place with 50% or more of CORE employees involved in each. By this definition, 36.6% of the entire sample, 43.0% of non-manufacturing establishments, and 35.9% of manufacturing establishments are of the new breed.¹¹ These estimates are considerably higher than those commonly cited, and although the definition is admittedly arbitrary, it is likely that the truth is much closer to these figures than to those found in popular accounts (recall also that only CORE jobs are being considered here).

¹⁰Again, Lawler, Mohrman, and Ledford find roughly similar patterns. For example, 64% of firms in their sample viewed TQM and various forms of employee involvement as distinct programs that are not jointly managed (Lawler, Mohrman, and Ledford 1992:104).

¹¹The Commission on the Skills of the American Workforce used the criterion of whether firms hired on the basis of a skill as opposed to behavior or ability to "get along." They assumed that firms that sought hard skills used them and hence were high-performance organizations. The distinction between hard skills and behavioral skills is not conceptually clear, nor is the assumption that one can go from knowing about hiring rules to understanding work organization. Leaving aside these problems, however, the current survey can also provide estimates along these lines. In an open-ended question, I asked establishments what were their first and second most important hiring criteria for CORE jobs. I coded their responses into various categories. If high-performance firms are defined as those listing hard skills as their first most important hiring criterion, 36.2% of establishments in the sample were high-performance; if only those establishments that listed hard skills as both their first and second most important criteria are counted, only 13.2% were high-performance.

Explaining the Distribution of Work Practices

The next step is to try to understand why some establishments have adopted these various work practices while others have not. I will estimate three models that use alternative dependent variables as measures of the establishments' overall profile with regard to flexible work systems. Details on the estimation methods are provided below.

The independent variables are intended to test many of the explanations that have appeared in the literature concerning variation in the adoption of flexible work practices across establishments. These explanations can be categorized as follows.

Markets and strategy. It seems reasonable to suppose that the nature of an establishment's competitors and of its market will influence the choice of work systems. The relationships, however, are not necessarily simple and straightforward. Consider first competitive pressure. Normally, one might expect that an establishment selling in a market with many competitors will be under pressure to adopt the most productive possible work system, and this tendency may indeed lead to elements of flexible work organization. Offsetting this tendency, however, is the consideration that new work systems represent considerable investment, and firms that face very competitive market situations may be operating on too tight a margin to undertake these long-run investments. The variable measuring the competitiveness of product markets is called *COMPETIV*.¹²

In addition to the degree of competition in the market, it is also important to consider the identity of the competitors. Much of the pressure to adopt new production systems has come from the example of foreign competitors, and this pressure probably is felt most strongly by enterprises that compete in

¹²The respondent was asked whether there were many firms, a few firms, or no firms selling products or services that competed with the establishment. The variable is coded "1" if there are many competing firms and "0" if there are no competing firms or a few competing firms.

international markets. In addition to this market argument, it seems reasonable to expect that establishments operating in international markets are more likely to be exposed to new ideas and practices than are those operating only in domestic markets.¹³ The variable *INTERNAT* is a dummy variable equal to "1" if the establishment sells in international markets.

A second aspect of an establishment's market concerns its competitive strategy. It is commonly posited that employers face the choice of either competing on the basis of cost or competing on the basis of quality, variety, and service (Piore and Sabel 1984; Cuomo Commission 1988; Kochan and Osterman 1991). In popular discussion, the former is referred to as the "low road" and the latter as the "high road," on the assumption that the latter implies more generous employment conditions (such as wages) and new work systems.

The survey contained a set of questions intended to distinguish between these strategies. I assigned 100 points to the goal of competing on cost and then asked the respondents to indicate how many points three other competitive strategies—quality, variety, and service—would receive for their establishment in comparison. For example, if the respondent considered competing on quality twice as important to the establishment as competing on cost, he or she would assign 200 points to competing on quality. I employ the first principal component of the three variables, and this component is termed *STRATEGY*. Larger values of this variable imply greater use of the "high road" strategy.¹⁴

Technology. An important aspect of technology is its complexity. It is reasonable to expect that the gains from the introduction of flexible work systems, and hence the likelihood that such systems will be introduced,

are greater under more rather than less complex technologies. The extent of complexity is measured by the variable *SKLEV*, which equals "1" if the production process requires high levels of skill and "0" otherwise.¹⁵

Values. It is well known from anecdotal evidence that firms that appear to observers to be similar with respect to markets, technology, and other structural characteristics nonetheless differ considerably in human resource practices.¹⁶ One possible explanation for such differences is differing values from firm to firm. For example, firms may differ in the extent to which the enterprise is seen as a community or a "family." Many observers believe that Japanese employers have more of a community or stakeholder view of their enterprise than do American employers, and this difference helps explain various differences between work practices in the two countries (Dore 1973; Lincoln and Kalleberg 1990). Kochan, Katz, and McKersie (1986) cite management values as an important determinant of HRM practices.

About 50% of the survey instrument consisted of a long series of questions about benefits, particularly work-family benefits, and about enterprise values regarding these benefits. This portion of the questionnaire was administered before the work organization questions that are the subject of this paper, and hence the respondents' answers to values questions were uninfluenced by the work organization section. The key values question in the benefits section was, "In general, what is your establishment's philosophy about how appropriate it is to help increase the well being of employees with respect to their personal or family situations?" Establishments that responded (on a five-point scale) that it was "very" or "extremely" appropriate are assigned "1" on the dummy variable *VALUE*.¹⁷

¹⁵Respondents were asked to characterize the skill level of the CORE jobs on a 1-5 scale; *SKLEV* is coded "1" if the reply was "very skilled" or "extremely skilled."

¹⁶In the computer industry, Data General and Digital Equipment Corporation are two firms that have taken very different approaches over the years. In the steel industry, USX and National or Inland are examples.

¹⁷The distribution of responses on the five-point scale was 1.7% "not appropriate," 9.4% "a little appro-

¹³For example, in the automobile industry quality circles were included in contract language as early as 1973, but were implemented on a wide scale only after pressure from Japanese competitors became intense (Katz 1985).

¹⁴The eigenvalue for the first component was 1.896 and the proportion of variance accounted for by this component was 63.2%.

Firm environment. An increasingly common argument is that some companies fail to transform their work organization because such transformations are long-term investments with considerable up-front costs and uncertainty. Many firms, so it is alleged, face pressures from investors to emphasize short-term profits at the expense of such long-term investments (Porter 1992; Jacobs 1991). The variable HORIZON measures the extent to which the establishment feels such pressure.¹⁸

There are several other environmental features that may influence the adoption of new work systems. Establishments that are part of larger organizations (a branch plant, for example) may receive greater resources, information, and technical assistance in adopting flexible work organization than do independent establishments. In addition, they may be more likely to adopt flexible work systems due to isomorphic processes of coercion and mimicry (DiMaggio and Powell 1983; Pfeffer and Cohen 1984; Baron, Jennings, Devereau, and Dobbin 1988). A dummy variable LARGER takes on the value of "1" if the establishment is part of a larger organization.

Size is likely to be related to adoption of flexible work practices, but the direction of the effect is ambiguous. On the one hand, smaller establishments have fewer resources to devote to human resource innovations. The literature on training, for example, demonstrates clearly that smaller firms train less than do large ones (Bishop, n.d.). On the other hand, the literature on corporate reorganization and decentralization (as well as the policy discussion of networks) suggests that smaller establishments, which are not weighed down by the heavy hand of corporate bureaucracy, are more agile and more likely to adopt new production techniques than are large establishments. In order to test

appropriate," 33.0% "moderately appropriate," 42.8% "very appropriate," and 12.8% "extremely appropriate."

¹⁸The respondent was asked to indicate on a five-point scale the extent of pressure the establishment felt from investors or any larger organization of which it was part to attain short-term profits at the expense of long-term investments. This five-point scale was recoded into a dummy variable equal to one if the respondent felt "very much pressure" or "extreme pressure."

for possible non-linear effects of size, I use a step function, that is, a series of size dummy variables. The omitted category is 100-499 employees.

The organizational sociology literature suggests that the age of an establishment (for which the variable AGE is entered) should inversely influence its rate of adoption of innovations, because organizational forms tend to be "frozen" at birth (Stinchcomb 1965). Finally, whether a union is present seems important, although the expected direction of the effect is not clear. There is considerable anecdotal evidence of unions opposing the kinds of work rule changes that are implied by transformed systems, but there are also instances in which unions have been cooperative and helpful in the process (Katz 1985; Cappelli and Sherer 1989). The net effect is an empirical question. The variable UNION measures whether employees at the establishment are covered by a union.

The models also include dummy variables for the CORE occupations and for industry.¹⁹

Estimation

An important difficulty is that there is no single obvious way to estimate a model explaining adoption of flexible work practices. One natural strategy is to combine the practices and ask about an establishment's overall rating. This is particularly tempting since, as noted, about a third of the establishments have none of the designated flexible work practices. I will take three approaches to an overall characterization of the establishment. First, I will estimate a logit model in which the dependent variable equals one if an establishment engages in at least one of the practices at the 50% level of penetration and zero otherwise. The advantage of this variable is that it is straightforward and readily interpretable; the disadvantage is that it is a bit arbitrary, since an establishment with 49% penetration is given a zero. A second approach is to use principal components

¹⁹Cases were dropped in which there were missing values on the use of any of the practices. In addition, three establishments in mining were dropped because of collinearity problems.

Table 4. Variable Definitions and Means.

Variable	Definition	Mean
UNION	1 = a union is present; 0 = no union	.237
AGE	Years since establishment founded	24.675
COMPETITIVE	1 = establishment's product market is competitive	.620
INTERNATIONAL	1 = establishment sells in international markets	.299
HORIZON	1 = management feels pressure from investors or large organization for short-term profits	.219
SKILL	1 = CORE job is very or extremely skilled	.369
LARGER	1 = establishment is part of a larger organization	.660
STRATEGY	Principal component of points assigned to variety, service, and quality relative to cost	-.004
VALUES	1 = respondent affirmed that it is very or extremely appropriate for the establishment to accept responsibility for the personal and family well-being of the employees	.552
Size 1	1 = establishment has 50-99 employees	.509
Size 3	1 = establishment has 500-999 employees	.048
Size 4	1 = establishment has 1,000-2,499 employees	.026
Size 5	1 = establishment has 2,500+ employees	.006

analysis to construct a composite variable from the percentage of penetration of each of the four practices. I therefore create an index that is the first principal component of the four penetration variables, and this is treated as a dependent variable.²⁰ The third approach is to estimate an ordered probit model in which the dependent variable ranges from zero to four, with each point on the scale representing an additional work practice at the 50% penetration level.

Taken together, these three dependent variables seem to represent the range of ways in which one might form an overall characterization of an establishment. One model (the logit) asks whether any practice is used at all at the 50% level, another (the ordered probit) asks how many practices are used at the 50% level, and the third (the principal components) treats penetration as a continuous variable and creates an index of the four practices. Using all three models permits an

assessment of how robust the findings are across specifications.²¹

Means for the variables are shown in Table 4, and results of the estimation are presented in Table 5. The first column of Table 5 contains coefficients for the logit model concerning whether the establishment engages in any practices at the 50% level of penetration; the coefficients in the second column are for the principal components model; and the coefficients in the third column are for the ordered probit. The logit coefficients have been transformed so that they have a direct interpretation.²²

²¹In unreported regressions (using Tobit models) I also estimated models in which the dependent variables were the percentage penetration of each practice. The results of these equations are available upon request. The results are generally comparable to, but slightly weaker than, those reported here. In particular, the strategy variable and the variable measuring whether the establishment is part of a larger organization were significant in the equations for teams and job rotation but not in the quality circles or TQM equations.

²²In order to interpret logit coefficients as the marginal change in a probability given a one unit change in the independent variable, they need to be transformed.

²⁰The index is $.55 \cdot \text{TQM Penetration} + .43 \cdot \text{Team Penetration} + .38 \cdot \text{Rotation Penetration} + .59 \cdot \text{Quality Circle Penetration}$. The first principal component accounted for 44% of the variance and had an eigenvalue of 1.752.

Table 5. Determinants of Flexible Work Practices.
(t-Statistics in Parentheses)

Independent Variable	Logit; Any Practice $\geq 50\%$	Principal Components; Four Practices	Ordered Probit; No. of Practices $\geq 50\%$
UNION	.067 (1.211)	-.176 (1.461)	-.110 (.973)
AGE	-.001 (1.984)	-.001 (.551)	-.001 (.738)
COMPETITIVE	.065 (1.431)	-.197 (1.989)	-.079 (.836)
INTERNAT	.172 (3.194)	.267 (2.338)	.330 (3.05)
HORIZON	-.017 (.347)	.066 (.587)	.026 (.248)
LARGER	.090 (1.827)	.575 (5.371)	.441 (4.21)
VALUES	.163 (3.854)	.578 (6.131)	.509 (5.56)
SKILL	.099 (1.956)	.410 (3.781)	.300 (2.92)
STRATEGY	.058 (2.906)	.079 (2.378)	.108 (3.43)
SIZE 1	.083 (1.767)	.264 (2.549)	.325 (3.25)
SIZE 3	-.317 (3.254)	-.567 (2.646)	-.647 (3.06)
SIZE 4	.177 (1.269)	.183 (.646)	.263 (.983)
SIZE 5	-.192 (.783)	-.211 (.382)	-.257 (.495)
CONSTANT	-.478 (3.533)	-1.715 (6.126)	-.257 (.495)
Log Likelihood	-388.467	R ² = .242	-886.67
N	694	694	694

Note: The equation also includes controls for CORE occupation and for industry.

Several conclusions come through quite strongly. Most impressive is the importance of managerial values. In all equations, the coefficient on VALUE is positive and significant. This result is especially striking given that the question was asked in the context of attitudes toward employees' social and economic welfare, and not in regard to specific

The transformation is

$$\partial P / \partial X = \beta(P)(1 - P),$$

and this expression is evaluated at the mean probability in the sample.

issues of work organization. Evidently, independent of any productivity gains to be had from flexible work organization, establishments that believe that they have responsibility for employee welfare are more likely to adopt innovative work practices.

It is also striking that enterprises that sell in international markets are more likely to adopt work reform. This result is independent of the overall level of competition in the market. One possible interpretation of this pattern is that establishments that are exposed to international markets learn more quickly than others about alternative work practices.²³

The third variable that produces consistently strong results is skill level. As the skill levels required by an enterprise's technology increase, so does the use of the various work organization innovations.

These models also support the view that establishments that follow the "high road" are more likely to adopt flexible work practices. In addition, being part of a larger enterprise, that is, being a branch plant or office, also increases the likelihood of adoption of elements of flexible work organization. Finally, smaller enterprises seem more likely to use innovative work practices.

In none of the equations is there evidence in support of the time horizons argument, nor do the age or union status of an establishment appear to be very important.²⁴

Related Human Resource Policies

There is a widespread view that work organization changes need to be accompanied by

²³Causality may, however, run in the other direction. That is, it may be that only firms that are productive due to their adoption of flexible work organization are able to compete internationally. To determine the direction of causality, data on timing both of work reforms and entry into international markets are necessary. The survey did not collect these data.

²⁴Lawler, Mohrman, and Ledford (1992:97-98) present the results of significance tests of simple (that is, unconditional) correlation coefficients between the presence of TQM and some independent variables. They find that size, manufacturing, and the presence of foreign competition are positively correlated with the use of TQM, and unionization is negatively correlated.

supporting HRM practices. This view follows from an idea found in the internal labor markets literature that groups of rules fit together logically and that it is therefore not possible to randomly adopt particular practices (Osterman 1987). The prescriptive literature has taken a similar perspective (National Research Council 1986). Although it seems unlikely that we will find perfect real world adherence to these ideas (for example, some establishments will adopt flexible work organization without adopting all of the other HRM rules that the literature predicts), it is important both for theory and practice to learn whether there are indeed the kinds of interrelationships among personnel rules that are predicted. I first describe the kinds of supporting rules theory leads us to expect and then examine whether the survey data show an association between these practices and flexible work organization.

In order to achieve the flexibility inherent in systems such as team production, employees must be willing to change jobs more often and to rely less on rigid procedures governing who does what. In this survey, deployment rules were measured by asking two questions, one concerning the importance of seniority versus merit in promotions and one concerning the importance of insider preference versus outside hiring in filling vacancies.²⁵

Compensation is also a central HRM variable. The anecdotal evidence suggests that many firms that have moved toward more flexible work organization have accompanied the shifts in work systems with comparable changes in ILM rules governing wages. These firms presumably subscribe to the theory that when employees are given more power to determine outcomes, they should have a financial stake in enterprise success. There has been an explosion of innovations

²⁵The respondents were asked to respond to the following two questions on a five-point scale: "When you fill a CORE job above the entry level, how important is it to give preference to someone already employed in the establishment?" and "When you do fill a CORE job with someone already employed, how important is seniority in deciding who among the already employed gets the job?"

in pay systems, and the survey focused on three of the most popular: the respondent was asked whether or not the establishment had in place profit-sharing or bonuses; gain-sharing; and pay for skill. Separate questions were asked about each practice.²⁶

A second issue concerning wages is whether the establishment paid its employees a wage premium (or what might be termed an efficiency wage).²⁷ New work systems typically require more commitment, effort, and discretion from employees, and these qualities are just the ones that are alleged in the efficiency wage literature to be produced by wage premiums. In addition, to the extent that the firm wishes to be selective in hiring and establish a pool or waiting line of higher-quality employees, it will also pay a wage premium.

The implementation of flexible work systems would seem to require higher levels of skills than are typically required of employees in traditional mass production systems. One would therefore expect that investments in training would be higher in transformed work systems. Three training variables are used: one measuring the percentage of CORE employees who receive formal off-the-job training, one measuring the percentage of CORE employees who receive cross-training (training in skills other than those used directly in their current job), and one measuring the value placed on skill enhancement relative to other HRM goals. (The last variable is described in more detail below.)

Many advocates of flexible work systems have argued that firms adopting these systems must be prepared to provide enhanced levels of job security (Levine and Tyson 1990;

²⁶The wage practice questions referred to the entire establishment, not just the CORE family. In addition, pretest results suggested that it would be too difficult for the respondent to provide information on the percentage of employees covered by each program, so these data were not collected.

²⁷The question asked whether there was a policy in place to pay the establishment's CORE employees wages that were higher than, the same as, or lower than the wages for employees in comparable occupations in the same industry in the same geographic area. The variable is coded as "1" if the policy was to pay a higher wage.

Kochan and Osterman 1990). The logic is that for employees to be willing to give up work rules that provide them a degree of job security (in the sense of limiting the employer's ability to collapse jobs and hence reduce employment), they must be provided employment guarantees in return. Such job security is seen as an important element of the Japanese and even German systems, and a number of the new auto contracts, such as NUMMI and Saturn, have strong employment pledges. On the other hand, there have been widespread recent layoffs even in firms, such as IBM and DEC, that are thought to exemplify flexible work organization. I employ two questions concerning job security. The first is simply whether the establishment had made any explicit or implicit no-layoff pledge. The second is part of a series of questions asking the establishment to rank various human resource objectives.

As with the earlier strategy variable, respondents were asked to rank several human resource goals. The technique was to assign 100 points to a baseline objective, in this case controlling wage and benefit costs, and then ask respondents to assign points to each of three additional objectives: increasing employee commitment, increasing employee skill, and reducing employment levels.²⁸ The first two goals are expected to be positively associated, and the third (employment reductions) negatively associated, with flexible work systems.

The respondents were also asked about their use of temporary and contingent labor. (A distinction was made between in-house temporary help—employees who are on the establishment's payroll—and outside contractors, who are on a third party's payroll. Parallel questions were asked about each category.) The standard argument concerning temporary and contingent employees is that firms use them in order to buffer their core employees from the vicissitudes of the labor market. Since protection of core employees is more important in transformed work systems than in conventional work settings (both

²⁸These are distinct objectives in which reducing cost was described in terms of wage and benefit levels, not total labor costs.

because of the higher skill level of these workers and because greater security is necessary to obtain their cooperation in flexible work), a hypothesis is that there will be a higher fraction of contract and temporary employees in establishments that have adopted flexible work systems. A contrary argument is that use of contingent workers and temporary workers signals lack of commitment to investing in a permanent labor force.

One might also expect a high priority on human resource considerations in firms committed to new work systems. I asked respondents how great a weight HRM considerations are given when major decisions are taken by the establishment. The five-point scale answers were recoded to equal one if HRM was said to be "very" or "extremely" important.

Table 6 shows the mean value of these HRM variables for the entire sample and for two subgroups: establishments that engaged in any of the work organization practices at a penetration level of 50% or more, and those that did not. In addition, the table provides significance tests for the differences in the means between the two subgroups. These significance tests are based on regressions in which the dependent variable is the HRM practice in question and the independent variable is a dummy for whether the establishment has 50% or more penetration of at least one practice. The regressions also include controls for industry and CORE occupation.

This analysis shows that a number of the HRM practices are indeed related to adoption of flexible work practices.²⁹ There is

²⁹Some readers might prefer a technique such as cluster analysis to determine if the HRM practices fall together in recognizable ways. Although clustering is a reasonable alternative, as a first-round approach I find the strategy employed here more robust. Cluster analysis can yield numerous alternative outcomes on the same data depending on choices of metrics or distance measures, and there are no tests for goodness of fit (Nunnally 1978:430). Furthermore, simple examination of the means tells us that there is no HRM practice that is uniformly associated with the presence or absence of flexible work organization. Hence, the notion of distinct clusters is not necessarily appropriate.

Table 6. The Relationship Between the Presence of Human Resource Practices and the Adoption of Flexible Work Practices: Significance Tests.

Human Resource Practice	All	Establishment	Establishment	t-Statistic
		Has at Least One Flexible Work Practice with 50% Penetration	Has No Flexible Work Practice with 50% Penetration	
Gainsharing	.137	.144	.126	.946
Pay for Skill	.304	.364	.197	4.676**
Profit-Sharing/Bonus	.447	.478	.393	2.008*
Wage Premium	.365	.376	.345	.792
HRM Department Role	.541	.564	.501	2.338*
Percent in Off-the-Job Training	.320	.375	.219	4.838**
Percent in Cross-Training	.451	.529	.314	7.456**
Employment Security Policy	.398	.394	.404	.179
Points for Increasing Skill	136.664	142.849	125.899	2.651**
Points for Increasing Commitment	191.711	199.713	177.521	2.430**
Points for Reducing Employment	80.455	80.195	80.916	.851
Percent Contingent	.076	.066	.090	2.237*
Percent Temporary	.070	.071	.070	.915
Seniority Hiring	.708	.721	.701	.474
Seniority Promotion	.303	.313	.286	.211

Note: T-statistics are based on equations that include CORE occupation and industry controls.
*Significantly different at the .05 level; **at the .01 level.

clear evidence that skills and training are important; indeed, all three of the skill variables (percentage in off-the-job training, percentage who receive cross-training, and commitment to increasing skill) are significant. In addition, two of the four pay practices are significant, although neither gainsharing nor the wage premium variable proves important. A high valuation on attaining a committed work force is significant, a result that is indirectly reinforced by the negative and significant coefficient on the use of contingent employees. Finally, the role of the HRM department also differentiates establishments that use flexible work practices from those that do not.

These results support many of the propositions in the HRM and ILM literatures concerning the practices needed to underwrite flexible work organization.³⁰ The most sur-

³⁰These results can be compared to those of Ichniowski (1990), which are based on the survey of Delaney, Lewin, and Ichniowski (1989). Ichniowski did

prising exception is the lack of evidence that employment security is important. Also surprising is the finding of no evidence that seniority versus merit rules play a role. Both of these sets of variables can be thought of as capturing various aspects of job ownership.

not make the distinction used here between work practices and supporting HRM policies, but rather used cluster analysis to combine a wide range of practices and policies into several groups. The clustering procedure led to the identification of nine groups. These clusters included typical union firms (with, for example, strict seniority and grievance procedures), transformed firms (with flexible job design, high levels of communication between management and workers, and substantial training), and a range of intermediate forms. There was also a substantial number of firms with rules that fell into no discernible pattern. Thirteen percent of the establishments in the sample were the most traditional category, 13% were in the most transformed category, 46% fell between these extremes, and 28% were unclassifiable (Ichniowski 1990:15). Considerable caution is needed in making comparisons between these results and mine, both because of the differences in procedure and because of the very different sampling frames and response rates.

Evidently, contrary to expectations, it is possible to introduce innovations in work practices without reassuring employees that their jobs are not at risk. Some observers explain such results by arguing that workers are constructing their careers via movement among networks of firms rather than by staying put with one employer.³¹ On the other hand, in answer to a survey question on whether the expected employment of recent employees was the same as, less than, or greater than in the past, 43.8% of establishments that had adopted at least one of the four practices at a 50% level of use said the stay had lengthened, compared to only 34.9% of establishments with no practice at the 50% level of penetration.

Conclusion

This study has made considerable progress in documenting the extent of the diffusion of flexible work practices and in identifying their correlates. First, about 35% of private sector establishments with 50 or more employees appear to have made substantial use of flexible work organization in 1992. This result is broadly consistent with Lawler, Mohrman, and Ledford's (1992) investigation of quality programs in Fortune 1000 firms.

Second, the findings strongly confirm that a number of variables are positively associated with the adoption of flexible work practices: a market with international competition; a high skill technology; worker-oriented values; following a high-road strategy (emphasizing service, quality, and variety of products rather than low cost); and being part of a larger organization. Also robust are the findings that neither the presence of unions nor pressure to turn short-term profits seems to be an important consideration. The results also allow the identification of a set of HRM practices that underwrite adoption of flexible work systems. Chief among these are innovative pay schemes, extensive training, and efforts to induce greater commitment on the part of the labor force. By contrast, neither employment security nor policies on seniority versus merit as a

³¹For example, this point was made by my colleague Charles Sabel in a conversation.

basis for promotions seem to be important.

In addition to their interest as previously unavailable descriptions of national practice, these results can be read as supportive of many of the internal labor market theories that have emerged in the past several years concerning work reorganization. On the other hand, the results also contradict some important expectations. There do appear to be systematic differences between establishments that adopted no flexible work practices and those that adopted at least one (as indicated by the results of the logit model). Among firms in the latter category, however, the work practices did not seem to cluster together into a natural formation that one might characterize by any of the popular labels—"high performance work organization," for example, or "transformed" firm. Also quite surprising is the unimportance of some of the HRM practices, particularly employment security, as predictors of the use of flexible work organization.

These anomalies invite some reconsideration of received wisdom, but the implication is far from clear. One possibility is that we are observing establishments in the process of change, and that after some time more practices will be adopted and the clusters we expected to find will emerge. There is some support in the survey for this idea, given that 49.1% of the teams, 38.0% of the job rotation practices, 71.1% of TQM programs, and 67.9% of problem-solving groups or quality circles were introduced less than five years prior to the survey year of 1992.

Also possible, however, is the considerably more dramatic interpretation that we have been misled by a few well-publicized cases. In the United States there may be many paths for work reform. If that is so, we will want to know much more than we do about the pros and cons of different choices. In addition, the unimportance of employment security may reflect substantial changes in the boundaries of firms and internal labor markets.

At a minimum, it seems to me that these data indicate that it is too early to construct "ideal types" of internal labor markets or "transformed" firms. We first need a considerably more textured understanding of the range of practices and the direction of change.

APPENDIX

Following are the definitions the interviewers used when the respondent requested clarification.

Self-directed work teams. Employees supervise their own work, they make their own decisions about pace and flow and occasionally the best way to get work done.

Job rotation. Self-explanatory example: In some banking firms you spend six months in the real estate

division, 6 months in pension plans, etc. Simply rotating jobs.

Problem-solving groups/quality circles. Quality programs where employees are involved in problem-solving.

Total Quality Management. Quality control approach that emphasizes the importance of communications, feedback, and teamwork.

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The skill bias effect of technological and organisational change: Evidence and policy implications[☆]

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Abstract

Previous studies have suggested that technological change is the main cause of the recent increase in demand for highly skilled workers in developed countries. However, a more recent strand of literature has also introduced the “Skill Biased Organisational Change” hypothesis, according to which the increasing diffusion of new organisational practices within firms plays a role in the increasing demand for skilled workers. We estimate a SUR model for a sample of 400 Italian manufacturing firms, showing that upskilling is more a function of reorganisational strategy than a consequence of technological change alone. Moreover, some evidence of superadditive effects emerges, which is consistent with the notion that technology and organisation jointly affect the demand for labour.

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1. Introduction

The long-run empirical evidence from numerous developed countries indicates that the number of skilled workers has grown over time. In the past two decades the economic literature (see next section) has offered an explanation for this empirical evidence based on the so-called “Skill Biased Technological Change” (SBTC) hypothesis, according to which the reason for the upskilling of the labour force is the non-neutrality of technological change, which benefits skilled labour more than other production factors. Because technology is complementary to skills, acceleration in the rate of technological change increases the demand for skilled labour. Indeed, whilst the phenomenon of SBTC appears to be a long-term historical trend (see Nelson and Winter, 1982; Dosi, 1988; Goldin and Katz, 1998; Von Tunzelmann and Anderson, 1998), the diffusion of Information and Communication Technologies (ICTs) seems to have given new impetus to the substitution of unskilled for skilled workers. As technologies such as ICTs have proved successful in raising the marginal productivity of skilled labour relative to unskilled labour, they have also made it relatively cheaper to employ skilled workers in place of the unskilled. Accordingly, Wood (1995) and Michel and Bernstein (1996) argue that the 1980s witnessed an acceleration in SBTC which resulted in rising skill premia¹ in many countries (see also Aghion and Howitt, 2002). However, since the evidence for this acceleration is mixed (see Autor et al., 1998), one might contend that, within a multi-sector framework, it is mostly the sector bias of technological change that is in operation, rather than the factor bias usually mentioned by labour economists (for a definition, see Jones, 1965). This explanation is consistent with empirical evidence supporting the SBTC hypothesis for high-tech countries (such as the US and the UK) but not for medium or low-tech ones (including other European countries; see Section 2.1).

Given that the literature is inconclusive on whether technological change favours a certain factor of production, or whether it is more likely to occur in some sectors rather than others (see Haskel and Slaughter, 2002), some researchers have looked for other possible complementary explanations of the skill bias. Among

trade economists, these alternatives are connected to globalisation,² whereas among industrial and managerial economists they concern the reorganisation of production. In this paper, we assess the relative importance of technological and organisational change and the possibility that technology and reorganisation exert a joint superadditive effect on the demand for skills.

The paper is organised as follows. Section 2 presents some evidence for the general upskilling trend in manufacturing across developed countries and discusses the economic literature on the role of technological and organisational change as a possible explanation for the skill bias. Section 3 sets out our empirical analysis based on a sample of 400 Italian manufacturing firms, while policy implications are discussed in Section 4. Finally, some concluding remarks are made in Section 5.

2. Comparative evidence and survey of the literature

The OECD Secretariat collected comparative data on employment broken down by occupation (high and low-skilled white-collar workers and high and low-skilled blue-collar workers) for some OECD countries during the 1980s and the beginning of the 1990s (OECD, 1996, 1998). Unfortunately, this database has not been updated for the years since 1993. We have reconstructed more recent figures³ relative to the manufacturing sector alone for the G-7 countries, maintaining a dichotomous division between skilled workers (white-collar workers, WC) and unskilled (blue-collar workers, BC).

² This strand of literature supports the hypothesis that increased volumes of world trade and FDI cause a reallocation of the labour force, shifting activities involving unskilled workers towards the least developed countries, while activities involving the production of skill-intensive goods remain in the developed ones (Wood, 1994; for an empirical test on Italian data, see Manasse et al., 2004). Owing to a lack of data, testing this hypothesis empirically is often a difficult undertaking; however, some studies on the subject have failed to find strong support for this explanation of the skill bias (see Slaughter, 2000; Piva and Vivarelli, 2002, 2004). This hypothesis will not be discussed and tested in the present paper.

³ Data are not comparable *between* countries owing to different sources and various classifications of occupations (see the note to Fig. 1); however, they provide important information on the dynamics of the demand for skilled workers *within* each country.

¹ Defined as the ratio between the wages earned by high-skilled workers and the wages earned by low-skilled workers.

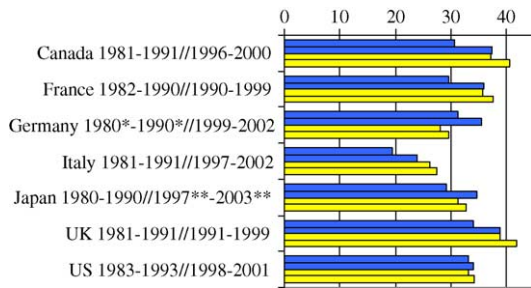


Fig. 1. Shares (percentage values) of white-collar workers in manufacturing employment in the G-7 countries. Notes: For each country, the two pairs of bars refer to the initial and final year of the two periods reported on the left. Source for data reported in the first periods is OECD (1998). Data for the second periods are our calculations based on the following national sources – Canada: Population Census, *Statistics Canada*; France: Recensements de la Population, *INSEE*; Germany: Employment Register, *IAB Germany*; Italy: Sistema Informativo Excelsior, *Unioncamere*; Japan: Labour Force Survey and Population Census (2003 data are relative to the month of June), *Statistics Bureau*; United Kingdom: Labour Force Survey, *Office for National Statistics*; United States: Population Census, *US Bureau of Labor Statistics*. Therefore, data are not comparable between countries, while within each country the two pairs of values are strictly comparable within them but not between them. In addition: * data for Germany refer to West Germany for the 1980–1990 period and to the whole of Germany for the 1999–2002 period; the inclusion of East Germany contributes to reducing the skill incidence in manufacturing employment. ** 1997–2003 data for Japan also include the construction sector, which explains the reduction of the skill incidence in the last period with respect to the previous one.

These data can be used to examine the changing skill composition. Fig. 1 depicts the change in the structure of manufacturing employment in the G-7 countries over the 1980s (OECD source) and the 1990s (our calculations based on national statistical sources). At first sight, there is a persistent upskilling trend of the workforce in all countries: the relative share of WC is increasing everywhere, even in most recent years (see also Piva and Vivarelli, 2002).

However, in most recent decades, the demand for skilled workers seems to have grown more rapidly than the corresponding labour supply, since skilled workers are not only more easily employed but, under certain circumstances, also proportionally much better paid than unskilled workers (see Nickell and Bell, 1995; Haskel and Slaughter, 2002).

Consistently with the different national institutional contexts, economists view skill bias as one of the possible determinants of the high unemployment that

afflicted continental European countries between the mid-1980s and the late 1990s (Machin and Van Reenen, 1998), and of wage dispersion between skilled and unskilled workers in the US and – to a lesser extent – the UK (Krueger, 1993; Autor et al., 1998).

Concern regarding the worsening socio-economic status of the unskilled has induced researchers to seek better understanding of the skill bias effect. The recent theoretical and empirical research on the matter can be surveyed by starting with the earlier studies, which only dealt with technological change, and then analysing the strand of literature that examines the role of organisational change, either alone or in interaction with technology.

2.1. Technology alone: the SBTC hypothesis

The SBTC hypothesis is based on the idea that there is close complementarity between new technologies and skilled workers, given that only the latter are fully able to implement those technologies.⁴ Empirical studies testing this hypothesis, at either the firm or the industry level, have been carried out on the manufacturing sectors of various developed countries. Most of these studies focus on the *factor bias* of SBTC.

As far as the US is concerned, there is substantial and consistent evidence supporting the SBTC hypothesis. Among the most recent and most representative papers, Berman et al. (1994) – at the sectoral level – and Dunne et al. (1996) – at the firm level – have found a positive and significant relationship between R&D and skilled labour in the US. Doms et al. (1997) – for firms in some US manufacturing sectors – have shown that the use of the most advanced industrial technologies leads to greater utilisation of workers with higher qualifications. Another test of the SBTC hypothesis was conducted by Siegel (1998), who found evidence of upskilling in those Long Island manufacturing plants that had introduced new technologies. With regard to a particular sector – US chemical firms – Adams (1999) showed the skill bias nature of R&D expenditure and innovative investments.

In Canada, both Betts (1997), who examined manufacturing, and Gera, Gu and Lin (2001), who focused on both the manufacturing and service sectors

⁴ For a theoretical survey, see Pianta (2004).

(1981–1994), demonstrated 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 1990s – and Haskel and Heden (1999) – at the firm level – demonstrated a positive relation between R&D intensity, number of innovations produced and used, and skilled labour (in the sector analysis), and both studies found a correlation between the use of computers and skilled labour in the case of firms.

The results of studies dealing with other countries have generally confirmed the SBTC hypothesis, although less robustly than in the case of the British and North American economies.

In France, Mairesse et al. (2001) obtained results similar to those of Machin (1996) for firm level data where the technological variables were ICT capital and ICT workers. However, only the negative relation between ICTs and less-qualified labour was robust in the time-series estimations. This confirmed the results of Goux and Maurin (2000), who showed that an increased spread of new technology accounted for only 15% of the change in labour demand between 1970 and 1993.

For Spain, Aguirregabiria and Alonso-Borrego (2001) used a panel of 1080 firms and tested the relation between new technologies and upskilling, using the GMM estimator for dynamic panels. Using a dummy representing the introduction of “technological capital”, they confirmed the SBTC hypothesis, while finding no significant effect with respect to R&D expenditure.

In Germany, Falk (1999) showed that the joint implementation of new products and processes had the greatest effect on the employment structure, exerting the strongest positive impact on the demand for university graduates. This result was also obtained by Falk and Koebel (2004), whose empirical analysis showed that the accumulation of office machinery and computer capital stock – in 35 German industries over the period 1978–1994 – was a significant factor in the shift of labour demand towards highly skilled workers (university graduates).

Machin and Van Reenen (1998) extended the analysis of the phenomenon beyond the national level. They set up a panel (at the manufacturing-sector level for seven developed countries over the period 1973–1989)

and showed that the relative demand for skilled workers was positively linked to R&D expenditure.

2.2. *Organisation alone: the SBOC hypothesis*

This second strand of literature is based on the hypothesis that the increasing diffusion of new organisational practices within firms plays a role in the increasing demand for skilled workers.

In general terms, organisational change is becoming increasingly important, and the empirical literature on the subject is growing rapidly in significance. The basic idea is that a progressive shift from rigid, Tayloristic, and segmented organisations towards more flexible and “holistic” ones is taking place within firms (see Lindbeck and Snower, 1996). This phenomenon first appeared in the US and Japan and has since spread through Europe, although with different intensities from country to country (see Aoki, 1986; Greenan and Guellec, 1994; O’Connor and Lunati, 1999). Space precludes a thorough summary of the vast amount of literature – whose basic notions originated with Chandler (1962) – on organisational change and its impact on firms’ structure and performance. Suffice it to say that economic, management and sociological studies on the subject seem to agree on the following recent trends (for a more detailed analysis, see Caroli, 2001): Decentralisation and delayering: “lean production” is associated with new firms’ functions, such as just-in-time, management of breakdowns and quality control, which in turn imply both the decentralisation of decision making and greater involvement, responsibility and autonomy at the shopfloor level (see Brynjolfsson and Mendelson, 1993; Greenan, 1996a; Bresnahan, 1999). Collective work: new working practices such as work teams and quality circles require collective effort by the workforce (see Osterman, 1994). Multi-tasking: workers are now required 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).

Moreover, the empirical literature reports that the organisational changes listed above generally occur at the same time, assuming the form of “clusters” of organisational innovations. For instance, Ichniowski et al. (1997), showed the complementarity of the introduction of teamwork, flexible job assignment and intensive workers-management communication in US steel man-

ufacturing (for an empirical study using Italian data, see Cristini et al., 2003).

Obviously, organisational innovation practices such as those briefly described imply that the manufacturing workforce must be upskilled. Accordingly, several authors have put forward and tested the “skill biased organisational change” (SBOC) hypothesis.⁵ For instance, Greenan and Guellec (1998), using a 1987 French survey on work organisation, found that organisational change – such as greater worker autonomy and increased communication among workers – was positively correlated with skill-upgrading.⁶ Again with regard to France, Thesmar and Thoenig (2000) and Caroli et al. (2001), using large databases of French manufacturing firms, found respectively a strong negative correlation between product turnover – taken as a measure of organisational “creative destruction” – and blue-collar workers, and a skill bias effect resulting from organisational change in association with a reduction in the firm’s size, which probably suggests an evolution towards more flexible firms. Caroli and Van Reenen (2001) compared two panels of French and British firms, focusing mainly on organisational change (measured with a dummy). Their results, which supported the SBOC hypothesis, proved to be econometrically significant in both the panels. Finally, Greenan (2003), using a survey on organisational change in French manufacturing in 1993, found that the increase in skill requirements was more closely connected to organisational than to technological change.

2.3. *Technological change associated with organisational change*

Whereas Aghion et al. (1999) maintained that technological progress was the main cause of change and that organisation was secondary, a recent strand of the literature has tended to emphasise that technological change and organisational change are complementary to each other, and that they often generate superadditive effects in terms of a firm’s performance, measured in terms of either productivity or profitability (see Pavitt

et al., 1989; Milgrom and Roberts, 1990, 1995; Black and Lynch, 2001; for a study using Italian data, see Pini and Santangelo, in press⁷).

Indeed, new ICTs modify the way in which decisions are taken in a firm, often making hierarchies redundant because orders are replaced by interactions among workers (see Bolton and Dewatripont, 1994). ICTs, moreover, on the one hand facilitate lateral communication because they enable layering into a flatter organisation, while on the other they increase the ability of shopfloor workers to perform information-intensive tasks (see Radner, 1993; Caroli, 2001; Colombo and Delmastro, 2002⁸).

In most countries, the introduction of ICTs does not appear to have generated any immediate and direct increase in productivity, probably because of the special nature of information technology. As pointed out by Gibson and Daldy (2003) in his study on computers and the wage structure in New Zealand, ICTs are mostly “general purpose technologies” (GPTs), whose main impact on the economy is not direct but occurs through a wide range of secondary innovations. Similarly, Mowery and Simcoe (2002) show that it took about 25 years (1960–1985) for the Internet to shift from public (mainly military and academic) to private/commercial applications, owing to the need for crucial complementary technological and organisational innovations. As a consequence, the introduction of a new GPT does not immediately result in a surge in productivity growth; at least as long as firms invest in developing these secondary innovations. This experimentation phase requires both workers who are skilled and workers who are “adaptable”, in the sense that they possess a combination of general knowledge and on-the-job experience that is not acquired from vocational and specific technical education alone but is also learnt from wide-ranging education and training.

The above theoretical considerations are supported by empirical evidence. For instance, on studying the

⁵ It should be noted that the economic literature has been most concerned with the consequences of organisational change on productivity, while there have been few attempts to focus directly on skills.

⁶ See also Greenan (1996b).

⁷ Conversely, the mismatch between technological change and organizational inertia may generate an adverse impact on a firm’s performance (the so-called “Solow paradox”; see Brynjolfsson et al., 1997; Brynjolfsson and Hitt, 2000).

⁸ Colombo and Delmastro (2002) find that organizational change (measured as a change in the number of hierarchical tiers within the firm) is largely explained by the adoption of advanced manufacturing technologies and flexible automation; however, their result holds true for both contractions and expansions of the managerial hierarchy.

Table 1
A summary of empirical analyses of skill bias

Country and period	Unit of analysis and methodology	Proxy for technology or/and organisation	Main results	Authors
Technology				
USA, 1979–1989	Sector, OLS in difference	Computer and R&D expenditure	Confirmation of SBTC hypothesis	Berman et al. (1994)
USA, 1972–1988	Firm, OLS in first differences, long difference and instrumental variables	R&D and introduction of industrial innovations	Confirmation of SBTC hypothesis for R&D	Dunne et al. (1996)
USA, 1987–1992	Firm, OLS in cross-section and time series	Investment in computers and industrial innovations	Confirmation of the SBTC hypothesis in the cross-section dimension but not in time-series	Doms et al. (1997)
USA, 1987–1990	Plants in Long Island, two stage probit for six classes of workers	Adoption of new technologies	Technology adoption increases the demand for all non-production workers and reduces that for production workers	Siegel (1998)
USA, 1974–1988	Firms (and plants) in chemical sector, SUR estimates	R&D and capital split into infrastructure and equipment	High skill bias effects due to firm R&D expenditure on the plant directly involved	Adams (1999)
Canada, 1962–1986	Sector, SUR estimates (estimated separately for each sector) for five inputs: WC, BC, capital, energy, raw materials	Temporal trend as proxy for technological change	Technological change is not neutral. Furthermore, in 11 sectors out of 18 there is a strong skill bias effect	Betts (1997)
Canada, 1981–1994	Sector (manufacturing and services), OLS	Stock of R&D, stock of patents used, Total Factor Productivity, age of capital stock	Confirmation of SBTC hypothesis: various technology indicators strongly correlated with skill intensity	Gera et al. (2001)
United Kingdom, 1979–1990, 1984–1990	Firm: 1984–1990, sector: 1979–1990, WLS in difference	Introduction of computers between 1984 and 1990 in firms, R&D expenditure for sectors	Confirmation of SBTC hypothesis both at sector and firm levels	Machin (1996)
United Kingdom, 1973–1992, 1986–1988	Firm, panel structure with pooling estimates and with fixed effects	Investment in computers	Skill-upgrading is mainly guided by phenomena within the firm. Computerisation significantly reduces the demand for unskilled workers	Haskel and Heden (1999)
France, 1970–1993	Sector, 2SLS	Computers and industrial technology	The increased diffusion of new technology explains only 15% of the change in labour demand	Goux and Maurin (2000)
France, 1986–1994	Firm, cross-section in long difference (4 years)	Investments in computers and office automation	Strong negative effect of the technological variable on the less skilled group of workers; the effect is robust in time-series	Mairesse et al. (2001)
Spain, 1986–1991	Firm, panel analysis using GMM estimator	R&D, technological capital, physical capital	Only the dummy for the introduction of technological capital has a strong negative effect on unskilled workers, especially during recessions	Aguirregabiria and Alonso-Borrego (2001)

Germany, 1997–1999	Firm, system of probit equations	Introduction of new products and processes	Joint implementation of new products and new processes has a stronger impact on the employment expectations of university graduates than do product innovations alone	Falk (1999)
Germany, 1978–1994	Sector, Box–Cox factor demand system	Office machinery and computer capital (OCM)	Accumulation of OCM capital stock is the major factor contributing to the shift in labour demand towards highly skilled workers	Falk and Koebel (2004)
Denmark, France, Germany, Japan, Sweden, United Kingdom and United States, 1973–1991	Sector, GLS in first difference	R&D expenditure	Faster skill-upgrading in sectors with more intensive R&D in all countries	Machin and Van Reenen (1998)
Organisation France, 1987	Individual/firm, descriptive approach on BC workers	Intensity of communication within the workshop and autonomy of workers	The skill of labour force is positively linked to both organisational variables	Greenan and Guellec (1998)
France, 1984–1995	Firm, OLS and OLS in long difference	Product turnover as a proxy of organisational “creative destruction”	Firms that experienced high product turnover were compelled to change their functional mix into more flexible functions requiring more skilled workers	Thesmar and Thoenig (2000)
France, 1989–1992	Firm, probit	Dummy on organisational change	Organisational change has a negative impact on the class of less skilled workers	Caroli et al. (2001)
France, 1992–1996; Great Britain, 1984–1990	Firm, OLS in long difference	Dummy on organisational change-delaying	The change in the number of skilled workers employed is significantly influenced by organisational change	Caroli and Van Reenen (2001)
France, 1993	Firm, multiple correspondence analysis	Different organisational structures: flexible enterprises, technical expertise firms, centralised and hierarchical firms, not flexible structures	Skills and organisational change are much more correlated than skills and technological change	Greenan (2003)
Technology + organisation USA, 1994	Firm, Spearman rank order correlation	Components of organisational architecture: decision rights, knowledge work and incentives. Proxies for technology: total capital stock of IT, computing power, PCs and networking technology	Greater level of ICTs is associated with increased delegation of authority to individuals and teams. Moreover, the combination of technological and organisational change involves skill bias both in the firms’ actual workforces and the recruitment strategies	Hitt and Brynjolfsson (1997)
USA, 1987–1994	Firm, OLS in cross-section in which demand for IT is partly controlled by the organisation variable	Technological capital, number of computers and organisational variable (changes in workplace)	IT combined with organisational change increases demand for skilled workers more than IT alone	Bresnahan et al. (2002)

impact of the implementation of advanced manufacturing technologies on human resource management (HRM) practices, Siegel et al. (1997) found a strong correlation between these technologies and enhanced employee empowerment.

Brynjolfsson and Hitt (1998) demonstrated that ICTs and new working practices cluster together. More specifically, the stock of IT capital and the number of PCs proved to be correlated with the diffusion of self-managing teams, workers' involvement in strategic decisions, and workers' discretion in planning their work.

Case studies at the level of individual firms are reviewed by Hitt and Brynjolfsson (2002), and they confirm the close complementarity between ICTs diffusion and the three types of firm-level reorganisation listed in Section 2.2 above.

Now that it has been demonstrated that technological change and organisational change often go together, some studies have also shown – not surprisingly, given the results discussed in Sections 2.1 and 2.2 above – that this combined modification of a firm's structure gives rise to an increase in the demand for skills. For instance, Hitt and Brynjolfsson (1997) surveyed about four hundred firms and found not only that greater levels of ICTs were associated with increased delegation of authority to individuals and teams, but also that the combination of technological and organisational change involved skill bias both in the firms' actual workforces and in their recruitment strategies.

More recently, Bresnahan et al. (2002), using data covering approximately 250 US firms (1987–1994) in cross-section, have demonstrated that labour demand has undergone structural changes in favour of skilled workers only when the introduction of computers has been accompanied by reorganisation within the firm.

2.4. A summary of the empirical literature

A summary of the empirical works discussed in the previous sections is given in Table 1.

The main findings of this literature can be summarised in the following points:

(a) North American and British empirical analyses usually support the SBTC hypothesis regardless of the level of analysis or proxy used to measure technology.

- (b) Less clear cut results are reported in empirical studies testing the SBTC hypothesis in continental European countries; moreover, some studies finding a positive relationship between technology and up-skilling reveal that this result is mainly driven by an adverse effect of technological change on the less skilled workers.
- (c) Empirical analyses specifically based on the SBOC hypothesis have been conducted in France and the US: these studies seem to show that new human resources practices in more flexible and decentralised organisations require skilled workers.
- (d) While different forms of organisational change tend to cluster, it has also been shown that organisational change as a whole is generally accompanied by technological innovation and new human resources practices.
- (e) The still few recent studies that have examined the correlation among new technologies, organisational change and skills suggest a superadditive skill bias effect of reorganisation combined with technological change.

In the following sections we will try to go a step further as regards previous empirical literature, the attempt being to jointly test the SBTC and SBOC hypotheses and assess both their relative statistical significance and the possible occurrence of superadditive effects.

3. Some results from Italian manufacturing

This section describes an empirical analysis of a sample of Italian manufacturing firms, the purpose being to assess whether technological change and reorganisation are possible determinants of the skill bias in a medium-technology country.

Table 2
Some descriptive statistics

	Sample (1991)	Population (1991)
Observations	400	4169
Employees (average)	351	310
Sales (average, million Italian lira)	93989	85478
R&D (%) 1989–1991	48	36.99
ORG (%) 1989–1991	41.75	37.80
ORG and R&D (%) 1989–1991	23.25	20.24

The data are taken from a representative database of Italian manufacturing firms with more than 11 employees (for details on the stratified methodology used to create the survey sample, see [Mediocredito Centrale, 1999](#)). This database comprises the replies to three questionnaire waves administered by the investment bank *Mediocredito Centrale* (MCC) in 1991, 1994 and 1997, with each questionnaire collecting retrospective data for 3 years.⁹ By considering only reliable and complete data strings overlapping the three waves and excluding obvious outliers,¹⁰ a sample of 400 firms was obtained.

[Table 2](#) provides some descriptive statistics.

As can be seen from [Table 2](#), our final sample turned out to be characterised by larger and more innovative firms in comparison with the entire survey population of 4169 firms.¹¹ In fact, the dynamic specification described below required selection of only those firms covered by all the questionnaire waves (the overlap was 561 firms and 400 firms after the cleaning procedure described above). These firms were larger and more innovative than the average; an outcome due to both of the survey methodology and to a “survivor bias”. As regards the former, while being stratified for smaller firms, MCC surveys attempt to include all manufacturing firms with more than 500 employees in all the waves (see [Mediocredito Centrale, 1999](#), p. 5). As regards the latter, larger and older firms are more likely to survive (see [Audretsch et al., 1999](#) and [Santarelli and Vivarelli, 2002](#)) and thus more likely to enter our overlapping subsample of 400 firms. While this sample selection is obviously detrimental to the representativeness of our analysis, it is also true that larger firms are more likely to be involved in the phenomena examined by this paper, namely technological and organisational change (this is the so-called Schumpeterian hypothesis; see [Schumpeter, 1942](#); [Audretsch, 1995](#); [Cohen and Klepper, 1996](#)). Thus, there is an obvious trade-off between the advantage of maintaining a fully representative sample of overall Italian manufacturing and that

of selecting a subsample where innovative firms make up about half of the firms examined (48%) and firms involved in organisational change more than 40%, which permits a more balanced empirical analysis of the impact of SBTC and SBOC.

With reference to skills, the MCC data enabled identification of two broad categories of homogeneous workers: white-collar (WC, including the entrepreneur and family assistants, senior and junior managers, and office workers) and blue-collar (BC, manuals).

The econometric specification is conducted within a theoretical framework based on the transcendental logarithmic (or translog) firm cost function. The model used is in long differences, with technological and organisational change referring to the 3-year period 1989–1991 and the dependent and controlling variables referring to the subsequent period 1991–1997. The advantages of this specification are that it eliminates firms’ fixed effects and possible problems of endogeneity (one such problem is that only firms which already have skilled workers have the potential for innovative investment: see [Acemoglu, 1998](#); [Kiley, 1999](#)). In this regard, it was not possible to use a dynamic panel structure (such as the GMM approach, see [Arellano and Bond, 1991](#); [Blundell and Bond, 1998](#)), because – in the MCC database – technological and organisational determinants were not represented by variables with a temporal structure, but only by qualitative dummies (and in the case of the organisational dummy, information was only available for the first wave, i.e. for the first 3-year period). However, long differences is considered the most viable method with which to test a dynamic specification in the absence of a time-series structure in the available data (for similar econometric strategies see [Machin et al., 1996](#); [Caroli and Van Reenen, 2001](#)).

In more detail, following a rather standard approach (see, among others, [Bartel and Lichtenberg, 1987](#); [Berman et al., 1994](#); [Machin and Van Reenen, 1998](#); [Caroli and Van Reenen, 2001](#)), the method used is based on estimation of a restricted cost function given only by the cost of labour (the only variable factors of production are the two categories of workers) while capital and technology are assumed to be quasi fixed factors for firm i :

$$LC_i = f(Y_i, K_i, w_{ij}, SB_i) \quad (1)$$

⁹ To avoid the use of misleading data, firms subject to takeover or break-up involving major employment discontinuities were excluded from the sample. For the few remaining cases, two dummies indicating whether the firm declared takeovers or break-ups were included in the econometric analysis (see below).

¹⁰ According to Grubbs’ test.

¹¹ The total number of firms is 4169 without any missing value on sales and employment in 1991.

where LC is the labour cost; f the translog functional form; Y the output; K the capital; w_j the wage for the j th category of workers (in our case $j=2$: WC the white-collars, i.e. non-manuals and BC the blue-collars, i.e. manual); SB the possible sources of Skill Bias, namely R&D and/or organisational intangible investments.

With all the variables in logarithms, minimisation of costs and implementation of Shephard's lemma, we obtain:

$$s_i = \frac{\partial \ln LC_i}{\partial \ln w_{i,WC}} = \varphi_i + \alpha \ln(Y_i) + \beta \ln(K_i) + \gamma \ln \left(\frac{w_{i,WC}}{w_{i,BC}} \right) + \delta \ln(SB_i) \quad (2)$$

where s_i represents the share of labour cost of white-collars.

To eliminate the φ_i fixed effects, we shift to a specification in differences (Δ) and we obtain the following stochastic form with a random error term (u):

$$\Delta s_i = \alpha \Delta \ln(Y_i) + \beta \Delta \ln(K_i) + \gamma \Delta \ln \left(\frac{w_{i,WC}}{w_{i,BC}} \right) + \delta \Delta \ln(SB_i) + u_i \quad (3)$$

In this specification, the relative wage variable carries a risk of endogeneity – owing to its collinearity with the dependent variable – and is generally eliminated or instrumented (see Chennells and Van Reenen, 2002, p. 184; Machin and Van Reenen, 1998, p. 1225, Eq. (2)). However, the specification proposed in (3) can be proxied by using information on employment (see Bartel and Lichtenberg, 1987, pp. 7–8), and in this case the dependent variable can be measured either as the ratio of white-collars (WC) to total workers or the ratio of white-collars (WC) to blue-collars (BC). Although less straightforward from a theoretical point of view, the specification in employment shares has been used – either alternatively or jointly with the specification in labour cost shares – by many researchers (see Berman et al., 1994, p. 384, footnote 12; Machin, 1996, p. 139ff. and Tables 7.4–7.6; Doms et al., 1997, p. 270, Eq. (2); Machin and Van Reenen, 1998, pp. 1226–1230 and table Appendix 1; Siegel, 1998, Eq. (5) and Table 8; Aguirregabiria and Alonso-Borrego, 2001, Eqs. (1) and (5)). The advantages of this alternative specification are that it enables direct testing of the sources of the skill bias in the demand for labour (that is, on the employ-

ment component alone isolated from the wage component) and that it does not require instrumentation of the wage regressor (see Chennells and Van Reenen, 2002, p. 178).

Starting from the general specification (3) with WC/BC as dependent variable, we used a Seemingly Unrelated Regression (SUR; see Zellner, 1962) method jointly testing two equations: one for the white-collars and one for the blue-collars. This method is based on the assumption that the right-hand part of the equation is independent of the error term, that the errors are crossed, and that the method therefore guarantees greater efficiency compared with an OLS estimation of the single equations. These assumptions are likely to hold in our specification (see Eq. (4) below), where basically the same equation (demand for labour) is applied to two different components (WC and BC) of the same workforce within the same unit of analysis, that is, the firm (for examples of previous papers using the SUR methodology in the empirical investigation of the sources of the skill bias, see Betts, 1997, p. 146, Eq. (2); Adams, 1999, p. 501, Eq. (5); for a discussion of this methodology, see Sanders and ter Weel, 2000, pp. 22ff.).

In this context, in our joint econometric specification the dependent variables are the log of differences (1991–1997) in WC and BC. The aim is to test the role of the two possible determinants of skill bias – measured as dummies which indicate the presence or absence of R&D expenditure and organisational change (ORG)¹² in the previous period 1989–1991 – controlling for contemporaneous determinants such as output (sales), capital and labour costs (WC and BC wages) which may influence the causal link we want to explore. Because the average annual wages of WC and BC workers were not provided by the MCC database, they were calculated by merging the MCC sample with the INPS (Italian National Institute for Social Secu-

¹² For R&D the question in the questionnaire was “whether the firm has carried out investments in R&D activity during the past 3 years” and for ORG “whether the firm has carried out significant organisational changes in its structure”. Although oversimplifying, these questions (the only ones available in the first 1989–1991 wave, which unfortunately did not include any other possible measure of R&D intensity) were addressed to the top managers of medium and large firms (see Table 2). Hence their answers should be considered homogeneously reliable.

Table 3
SUR estimates of changes in the demand for WC and BC between 1997 and 1991 (R&D and ORG)

	(1) dIWC	(2) dIBC	(3) dIWC	(4) dIBC	(5) dIWC	(6) dIBC
Constant	0.17 (1.34)	0.12 (1.17)	−0.13 (1.83)*	−0.05 (0.64)	0.16 (1.33)	−0.05 (0.64)
Sales	0.32 (5.79)***	0.38 (6.34)***	0.31 (5.64)***	0.39 (6.58)***	0.31 (5.51)***	0.40 (6.60)***
Capital	0.04 (1.11)	0.09 (2.49)**	0.04 (1.02)	0.10 (2.62)***	0.04 (1.04)	0.10 (2.57)***
Wages	−0.60 (6.96)***	−0.004 (0.04)	−0.59 (6.91)***	−0.01 (0.15)	−0.59 (6.88)***	−0.01 (0.14)
R&D	0.02 (0.36)	−0.01 (0.19)				
ORG			0.06 (1.46)	−0.08 (1.83)*		
ORG × R&D					0.09 (1.78)*	−0.10 (1.82)*
Fixed effects						
TB	5.56*	1.21	5.95*	1.18	5.86*	1.23
Size	25.75**	12.53***	26.20***	10.42**	27.29***	11.21**
Sector	0.53	2.35	0.40	2.58	0.78	1.81
R ²	0.23	0.19	0.24	0.20	0.24	0.20
Observations	400	400	400	400	400	400

t-statistics in brackets. R&D and ORG refer to the 3-year period 1989–1991; WC, BC, sales, capital and wages are all expressed as a difference of the logarithm (1997–1991). With reference to the fixed effects (TB = takeovers and breakups; size = five firm size classes; sector = four-sectors Pavitt's taxonomy) the result of a Wald test is given, under the null hypothesis of zero value of the relevant dummies. All three models prove to be superior to OLS estimates, according to the relative Breusch–Pagan's tests: $\chi^2(1) = 75.355^{***}$, $\chi^2(1) = 74.356^{***}$, $\chi^2(1) = 74.008^{***}$.

* Significant at 10%.

** Significant at 5%

*** Significant at 1%.

rity) database.¹³ All the variables were deflated and expressed according to 1990 prices. Capital, *K*, was derived from the balance sheet item “net technical assets”, while output, *Y*, was quantified in terms of sales.

Formally, we tested the following specification:

$$\begin{cases} \Delta \ln(WC_{it}) = C + \alpha \Delta \ln(Y_{it}) + \beta \Delta \ln(K_{it}) \\ \quad + \gamma \Delta \ln(w_{WC_{it}}) + \lambda SB_{i,t-1} + u_{it}, \\ \Delta \ln(BC_{it}) = \bar{C} + \bar{\alpha} \Delta \ln(Y_{it}) + \bar{\beta} \Delta \ln(K_{it}) \\ \quad + \bar{\gamma} \Delta \ln(w_{BC_{it}}) + \bar{\lambda} SB_{i,t-1} + \bar{u}_{it} \end{cases} \quad (4)$$

with $SB_{i,t-1}$ (Skill Bias dummy) = alternatively: $R\&D_{i,t-1}$, $ORG_{i,t-1}$ and $R\&D_{i,t-1} \times ORG_{i,t-1}$.

Additional controls were included: four Pavitt-sector fixed effects (Pavitt, 1984), five firm-size fixed effects (11–20; 21–50; 51–250; 251–500; >500 employees), and two fixed effects related to takeovers or break-ups (TB) declared in the period 1991–1997.

Table 3 presents the results. The first finding (columns 1 and 2) suggests that the alleged role of R&D alone in determining skill bias is not robust to

the econometric control.¹⁴ As a matter of fact, Italian manufacturing comprises a large fringe of family businesses – some of them relatively large in size, like most of those in our sample (see Table 2) – either operating in traditional industries or below the technological frontier when active in advanced sectors (see Burkart et al., 2003). Hence, consistently with the findings of Haskel and Slaughter (2002), in the case of our sample the shift from unskilled to skilled labour is unlikely to be driven uniquely by in house RD activities.

The ORG variable instead affects the demand for BC and WC with the expected signs and proves to be significant in determining redundancy among the unskilled. This is consistent with a view of Italy that originated with Fuà (1988), who stressed the importance of the so-called organisational-entrepreneurial factor

¹³ This complex and costly merging procedure was restricted to the sample of 400 firms and not extended to the entire MCC database. It is for this reason that wages do not appear in Table 2.

¹⁴ Nor can significant effects of the technological variables be found in Aguirregabiria and Alonso-Borrego (2001) with regard to Spanish firms, in Greenan (2003) with regard to French firms or in Caroli and Van Reenen (2001) again with regard to French firms. Of course, this finding does not rule out a possible role by other forms of technological change – not detectable in this study – such as knowledge embodied in new machinery and capital equipment and acquisition of information relevant to innovation projects from clients and/or suppliers (see Piergiovanni and Santarelli, 1996; Piergiovanni et al., 1997).

Table 4
SUR estimates of changes in the demand for WC and BC between 1997 and 1991 (SHOPFLOOR)

	(1) dIWC	(2) dIBC	(3) dIWC	(4) dIBC
Constant	-0.13 (1.76)*	0.13 (1.30)	-0.14 (1.90)*	0.12 (0.86)
Sales	0.31 (5.64)***	0.39 (6.60)***	0.30 (5.45)***	0.40 (6.70)***
Capital	0.04 (1.05)	0.10 (2.60)***	0.04 (1.05)	0.10 (2.58)***
Wages	-0.59 (6.94)	-0.01 (0.12)	-0.59 (6.91)***	-0.01 (0.12)
SHOPFLOOR	0.05 (1.22)	-0.09 (1.91)*		
SHOPFLOOR × R&D			0.09 (1.83)*	-0.12 (2.20)**
Fixed effects				
TB	6.12*	1.20	6.04**	1.14
Size	26.18***	14.73***	26.95***	11.15**
Sector	0.42	2.66	0.81	1.88
R ²	0.24	0.20	0.24	0.20
Observations	400	400	400	400

t-statistics in brackets. SHOPFLOOR and R&D refer to the 3-year period 1989–1991; WC, BC, sales, capital and wages are all expressed as a difference of the logarithm (1997–1991). With reference to the fixed effects (TB = takeovers and breakups; size = five firm size classes; sector: four-sectors Pavitt's taxonomy) the result of a Wald test is given, under the null hypothesis of zero value of the relevant dummies. The two models prove to be superior to OLS estimates, according to the relative Breusch–Pagan's tests: $\chi^2(1) = 74.520^{***}$, $\chi^2(1) = 73.619^{***}$.

* Significant at 10%.

** Significant at 5%.

*** Significant at 1%.

in re-shaping the profile of those Italian firms which do not rely on their own R&D as the sole source of change.

Finally, in columns (5) and (6) an interaction dummy representing the joint presence of ORG and R&D exhibits higher and more significant coefficients when compared to ORG in the previous estimates (3) and (4).¹⁵ This result suggests a superadditive skill bias effect of reorganisation combined with technological change, and it is consistent with the findings summarised in Section 2.3 above.

For a more detailed investigation of the role of ORG in reshaping the composition of the demand for labour, we were able to use an additional piece of information from the original MCC questionnaire. As far as organisational change is concerned, the complete question was: “whether the firm has carried out significant organisational changes in its structure and, if yes, in which business function (Marketing, Distribution, Production, Finance, Administration, Management, Quality control, Other)”. Testing the impacts and joint interactions of different dummies for each of these firm's

functions, we found that the variable ORG was mainly driven by changes at the SHOPFLOOR level, including transformations in the Production and Quality Control business functions.¹⁶ In its turn, this specific variable exhibited a better statistical performance than did the general dummy ORG (see following Table 4).

As shown by the results in Table 4, organisational changes at the shopfloor level affect the relative demand for WC and BC with the expected signs, while a clearer superadditive effect emerges from the significant coefficients in columns (3) and (4).¹⁷ A peculiarity of the Italian case is that both the sole impact of SHOPFLOOR and the joint effect of SHOPFLOOR × R&D seem to be unbalanced both in terms of statistical significance and the values of the coefficients. In other words, organisational change at the level of the workforce mainly implies the redundancy

¹⁵ Note that the simultaneous inclusion of the three dummies – R&D, ORG and ORG × R&D – is not econometrically appropriate due to the obvious high collinearity between the interaction variable and its two components (the linear correlation between R&D and ORG × R&D is 0.57 and between ORG and ORG × R&D is 0.65).

¹⁶ SHOPFLOOR assumes value 1 when there has been an organisational change either in the Production function or the Quality Control procedure or in both; the linear correlation between ORG and SHOPFLOOR was equal to 0.92. The SHOPFLOOR dummy assumes a value of 1 in 38% of firms in the sample (while it assumes a value of 1 in 21.94% of the entire population).

¹⁷ Changes in all the other business functions were found to be statistically not significant in their impacts on the relative demand for WC and BC workers.

of blue-collars while it weakly increases the demand for white-collars.

4. Policy implications

The descriptive statistics for the G-7 countries presented in Section 2 show a clear upskilling trend in manufacturing industries over the 1980s and 1990s. In the case of Italy, the analysis of a sample of manufacturing firms carried out in the present paper shows that the upskilling trend of employment appears to be mainly a function of the reorganisational strategy adopted by the firms, possibly combined with technological change. Moreover, shopfloor reorganisation appears to have slightly favoured more skilled workers, whereas blue-collar workers seem very vulnerable to the joint effect of reorganisation and the implementation of new technologies.

In terms of policy prescriptions, these findings suggest that reorganisational strategies should be coupled with intervention regarding HRM at the level of the firm, especially with regard to production workers. Indeed, the lack of complementary manpower strategies increases the likelihood of redundancy among blue-collar workers, who may be particularly exposed to labour-saving organisational and technological changes (for instance, according to the empirical results by Wolff (1995), “motor skills” seem to be affected by a long-term absolute decline, see also Freeman and Soete, 1994). Hence, policy makers should support holistic strategies at the level of the firm (on-the-job training aimed at transferring updated capabilities to workers), and they should promote education and off-the-job training. In other words, only education and training can maximise the joint impact of technological and organisational change on firms’ performance and aggregate welfare.

One can go a step further and suggest a “three angle” management strategy where organisation, technology and skills are the components of the triangle (see Caroli, 2001). According to this view, our results show that a good match between these different factors seems to hold at the white-collar level, while a possible mismatch negatively affects the demand for blue-collars. In this framework, blue-collars are not necessarily “victims” of intrinsically labour-saving technological and organisational change; they are only nega-

tively affected by an inefficient mix of ICTs and new working practices.¹⁸ If this is the case, HRM and education policies may decisively mitigate the impact of technological and organisational change upon the most vulnerable workers.

Turning to education and training policies, some of the previous literature suggests that workers are better off with general rather than vocational education, because their skills are in this case less likely to be rendered obsolete by technological progress (see Nelson and Phelps, 1966; Maurin and Thesmar, 2004).

This policy implication appears to be consistent with the view of ICTs as pervasive “general-purpose technologies” applicable across a wide range of functions and tasks (see Bresnahan and Trajtenberg, 1995; Freeman and Louçã, 2001).¹⁹ On this view, both technological change alone and any parallel organisational change require general and adaptable skills rather than specific competencies. In this regard, Krueger and Kumar, 2004b, use OECD data to show how the US surpasses Europe in providing general tertiary education: they show that the ratio of general to vocational education subsidies in post-secondary school is equal to 1 in Germany and Italy, while it is 2.55 in the US. This evidence is considered by the authors as a possible determinant of higher productivity gains and economic growth in the US, compared with Europe (see also Krueger and Kumar, 2004a).

Indeed, when new technologies and new organisational practices require the workforce to have task, functional and sectoral flexibility, and make specific skills rapidly obsolescent, secondary and tertiary education should be targeted more on general content, models and methodologies rather than on specific technical competencies. According to Bresnahan (1999) and Bresnahan et al. (2002), general education should

¹⁸ We thank one of the referees for suggesting this line of interpretation.

¹⁹ Moreover – and beyond the scope of this paper – it should be borne in mind that ICT-based general purpose technologies also massively affect the services sector (see Kleinknecht, 2000), with the processes of SBTC and SBOC occurring in a similar manner to those detected in manufacturing activities and affecting both service workers and service consumers (see Petit and Soete, 2001). Among studies which consider the skill bias in services as well as in manufacturing, see Autor et al. (1998), Gera et al. (2001), Mairesse et al. (2001), Falk and Koebel (2004). However, only a few studies have specifically investigated skill bias in the service sectors (see, for instance, Kaiser (2000) and Evangelista (2000)).

also deliver a number of “non-cognitive” skills, ranging from interpersonal skills to the ability to work steadily and autonomously, from flexibility to an ability to influence team-mates and inspire subordinates (quite consistently, Wolff (1995), finds that the demand for “cognitive skills” was strongest in the 1960s than in the 1980s).

These prescriptions seem to be consistent with the empirical results discussed in the previous section: if skill-upgrading is not triggered by technological change alone, but mainly by organisational change (possibly combined with the former), the need for engineers and IT technicians no longer emerges as paramount, while the increasing demand for a multi-skilled and easily adaptable workforce calls for an increase in the supply of general education and training at the high and intermediate levels. The latter seems to be particularly important, since workers’ greater involvement and autonomy require general knowledge even at the level of the shopfloor (blue-collar) and at that of routine clerical work.²⁰

For instance, Torrasi (1998) – in his study on the software industry – shows that high-level specific skills for ICTs, such as mathematics and computer science, should be coupled with intermediate and less specific skills based on work experience and system engineering. However, Torrasi also shows that “general-purpose” capabilities (more connected with general education) are just as important as “context-specific” ones (more closely connected with vocational education and training). Indeed, the former prove to be crucial in absorbing knowledge from universities and competitors, while the latter are important in relationships with users (Torrasi, 1998, pp. 144ff.). These considerations prompt an alternative view which sees general and vocational education as complements rather than substitutes.

Finally, if organisational change (possibly combined with technological change) proves to be “knowledge biased” for all levels of the workforce, the concept of a “learning society” warrants closer attention, and should shape the evolution of education policies. Thus, the building of a learning society should not be

seen solely as a necessary response to the technical challenges raised by the “new economy” and the ICT revolution; it should also be viewed as an institutional context favouring the diffusion of general knowledge, social and communication skills, and “learn how to learn” capabilities (see Lundvall, 1992; Lundvall and Johnson, 1994; Lundvall et al., 2002).

5. Conclusions

Recent theoretical and empirical studies have focused on the contemporaneous occurrence of technological and organisational change within firms. Using a unique database, this paper improves on the previous literature in jointly considering the SBTC and the SBOC hypotheses, otherwise generally tested in separate estimates.

In more detail, this paper offers new evidence on the effect of technological and organisational change on the skill composition of Italian manufacturing employment. In particular, it shows that:

- (a) The alleged role of R&D alone in determining skill bias is not confirmed by econometric estimations; this result is in contrast with previous evidence from US data, but consistent with previous empirical papers which have used European data from less technologically advanced countries.
- (b) Significant organisational changes made by a firm to its structure and particularly to its shopfloor functions are major factors affecting skill composition; in comparison with previous literature, this result suggests a possible dominant role of organisational change at the shopfloor-production level.
- (c) Combining R&D and the organisational variables yields a higher and more significant impact; this outcome is consistent with recent results from managerial literature based on case studies.

If this is the nature of the skill bias, a possible implication for education and training policies is that general knowledge – including non-cognitive capabilities – should be fostered. The correlated research question as whether general and vocational education are complements or substitutes in affecting both a firm’s performance and the aggregate economic growth is a matter for further investigation.

²⁰ For a similar opinion, see Steedman et al. (1991) and Caroli (2001). Indirect evidence on the unfulfilled need for more general knowledge at the intermediate and lower levels of the occupational structure is provided by the use of graduates at the shopfloor level, see Mason (1996) and Mason and Finegold (1997).

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