



# The skill bias effect of technological and organisational change: Evidence and policy implications<sup>☆</sup>

Mariacristina Piva<sup>a</sup>, Enrico Santarelli<sup>b, c, d</sup>, Marco Vivarelli<sup>a, c, e, f, \*</sup>

<sup>a</sup> *Catholic University, Department of Economic and Social Sciences, Via Emilia Parmense 84, I-29100 Piacenza, Italy*

<sup>b</sup> *University of Bologna, Department of Economics, Italy*

<sup>c</sup> *Max Planck Institute, Entrepreneurship, Growth and Public Policy Group, Jena, Germany*

<sup>d</sup> *ENCORE, Amsterdam, The Netherlands*

<sup>e</sup> *International Labour Office, ILO, Geneva, Switzerland*

<sup>f</sup> *Institute for the Study of Labour, IZA, Bonn, Germany*

Received 1 December 2003; received in revised form 15 November 2004; accepted 30 November 2004

## 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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*JEL classification:* O33; J50

*Keywords:* Skill bias; Technology; Organisational change; Manufacturing

<sup>☆</sup> This paper is part of the research project *Patterns and determinants of skill biased technical change in a medium-technology country*. Financial support from MIUR (year: 2001; protocol: #133591.002; project leader: E. Santarelli) is gratefully acknowledged. Previous versions were presented at the “Ninth Workshop on Alternative Economic Policy in Europe” (Free University of Brussels, 26–28 September, 2003), at the international workshop “Innovation, Employment and Economic Growth” (University of Bologna, 28–29 November, 2003), at the II International Industrial Organisation Conference (Chicago, 23–24 April, 2004) and at the Annual Meeting of the Administrative Sciences Association of Canada (Quebec City, 5–8 June, 2004).

Comments and suggestions by three anonymous referees and by Rita Almeida, Tom Astebro, Eugene Choo, Massimo Colombo, Annalisa Cristini, Andrea Fumagalli, Alfred Kleinknecht, Fabio Montobbio, and Mark Sanders have been extremely useful in improving the analysis.

\* Corresponding author. Tel.: +39 0523 599 301; fax: +39 0523 599 303.

*E-mail addresses:* [marco.vivarelli@unicatt.it](mailto:marco.vivarelli@unicatt.it), [vivarelli@ilo.org](mailto:vivarelli@ilo.org) (M. Vivarelli).

## 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 premia<sup>1</sup> 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,<sup>2</sup> 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 figures<sup>3</sup> 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).

<sup>2</sup> 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.

<sup>3</sup> 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.

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

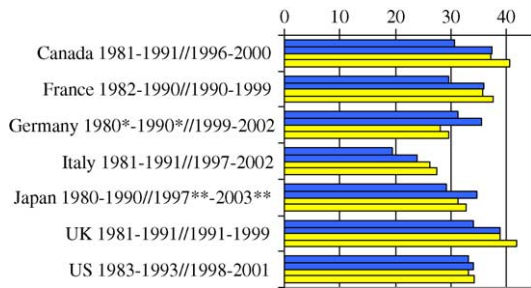


Fig. 1. Shares (percentage values) of white-collar workers in manufacturing employment in the G-7 countries. Notes: For each country, the two pairs of bars refer to the initial and final year of the two periods reported on the left. Source for data reported in the first periods is OECD (1998). Data for 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.<sup>4</sup> 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

<sup>4</sup> 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 layering: “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.<sup>5</sup> 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.<sup>6</sup> 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 press<sup>7</sup>).

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, 2002<sup>8</sup>).

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

<sup>5</sup> 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.

<sup>6</sup> See also Greenan (1996b).

<sup>7</sup> 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).

<sup>8</sup> 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.<sup>9</sup> By considering only reliable and complete data strings overlapping the three waves and excluding obvious outliers,<sup>10</sup> 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.<sup>11</sup> 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  $i$ :

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

<sup>9</sup> 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).

<sup>10</sup> According to Grubbs’ test.

<sup>11</sup> 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  $\varphi_i$  fixed effects, we shift to a specification in differences ( $\Delta$ ) 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)<sup>12</sup> 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-

<sup>12</sup> 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 <sup>2</sup>	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.<sup>13</sup> 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.<sup>14</sup> 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

<sup>13</sup> 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.

<sup>14</sup> 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 <sup>2</sup>	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).<sup>15</sup> 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.<sup>16</sup> 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).<sup>17</sup> 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

<sup>15</sup> 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).

<sup>16</sup> 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).

<sup>17</sup> 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.<sup>18</sup> 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).<sup>19</sup> 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

<sup>18</sup> We thank one of the referees for suggesting this line of interpretation.

<sup>19</sup> 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.<sup>20</sup>

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.

<sup>20</sup> 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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