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## The skill bias effect of technological and organisational change : evidence and policy implications

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Evidence and Policy Implications**

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# **The Skill Bias Effect of Technological and Organisational Change: Evidence and Policy Implications**

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## ABSTRACT

### **The Skill Bias Effect of Technological and Organisational Change: Evidence and Policy Implications\***

Previous empirical literature has shown that technological change can be considered the main cause of the skill bias (increase in the number of highly skilled workers) exhibited by manufacturing employment in developed countries over the last decades. However, recent papers have also introduced the “Skill Biased Organisational Change” hypothesis. We estimate a SUR model for a sample of 400 Italian manufacturing firms, showing that upskilling is more a function of the reorganisational strategy than a consequence of technological change alone. Moreover, some evidence of superadditive effects emerges, consistently with the theoretical hypothesis of a coevolution of technology and organisation.

JEL Classification: O33, J50

Keywords: skill bias, organisational change, manufacturing

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## 1. Introduction

The long-term empirical evidence for many countries shows that the number of skilled workers (in particular graduates) has grown over time. *Vis-à-vis* this process of “knowledge deepening” occurring in most production activities, a marked and widening wage inequality has been observed between more skilled and less skilled workers. This second item of evidence is in contrast with both the simple supply and demand view, according to which an increase in the number of skilled workers should result in less wage inequality, and the historical evidence dating back to the First Industrial Revolution, when low skilled labour and machines replaced skilled artisans. A possible explanation for this process is that, as the returns from education rise due to technology, more people respond to these pay incentives by acquiring tertiary qualifications, with a consequent increase in the supply of skilled workers. Nevertheless, there is also room for at least three other possible theoretical explanations, respectively identifying the main determinants of the observed shift from unskilled to skilled labour in technology alone, in reorganisation processes occurring within the firm, and in a combination of these two aspects.

In this connection, over 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; yet it is also true that an increase in the supply of skills induces faster technological change (see, among others, Greiner *et al.*, 2001).

One explanation put forward by economists to reconcile these facts hinges on the nature of technological change over the past two decades. 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 Technology (ICT) seems to have given new impetus to the substitution of unskilled workers by skilled ones. As technologies such as ICT proved successful in raising the marginal productivity of skilled labour relative to unskilled labour, they also made it relatively more economical to employ skilled workers in the place of unskilled ones. Accordingly, Michel and Bernstein (1966) and Wood (1995) 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. 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 is more likely to occur in certain sectors than in others (see Haskel and Slaughter, 2002), some researchers looked for other possible complementary explanations of the

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

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, which adopts the approach put forward by industrial and managerial economists, attention will focus on the role of organisational change and the possibility that technology and reorganisation exert a joint superadditive effect in influencing 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 changes 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 conclusive considerations are presented 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 a few OECD countries during the 1980s and the beginning of the 1990s (OECD, 1996 and 1998). Unfortunately, this database has not been updated for the years following 1993. We have

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<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 developed countries (Wood, 1994; for an empirical test on Italian data see Manasse *et al.*, 2003). 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 and 2004). This hypothesis will not be discussed and tested in the present paper.

reconstructed more recent figures<sup>3</sup> relative to the manufacturing sector alone for the G-7 countries, maintaining a dichotomic division between skilled workers (white-collar workers, WC) and unskilled ones (blue-collar workers, BC).

This data can be used to examine the changing skill composition. Figure 1 depicts the change in the structure of manufacturing employment in the G-7 countries over the 1990s. At first glance, there is a persistent upskilling trend of the workforce in all countries: the relative share of WC is increasing everywhere, even over the most recent years (see Piva and Vivarelli, 2002, for consistent previous results based on OECD data over the '80s).

Nevertheless, over the past few 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, they are also proportionally much better paid than the unskilled (see Nickell and Bell, 1995; Haskel and Slaughter, 2002).

Consistently with the different national institutional contexts, skill bias has caused increasing unemployment of unskilled workers in continental European countries (Machin and Van Reenen, 1998) and has had stronger effects on the wage dispersion between the skilled and unskilled in the US and - to a lesser extent - the UK (Krueger, 1993; Autor *et al.*, 1998).

Concern over the worsening social economic position of the unskilled has induced researchers to seek a better understanding of the skill bias effect. Recent theoretical and empirical research can be surveyed by starting with the early studies, which only dealt with technological

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



change, and then analysing the recent strand of literature which examines the role of organisational change, either alone or in interaction with technology.

< INSERT FIGURE 1 >

## **2.1 Technology alone: the SBTC hypothesis**

The SBTC hypothesis is based on the idea that there is a strong 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, either at the firm or the industry level, have been carried out with regard to 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 the 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.

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<sup>4</sup> For a theoretical survey, see Pianta (2003).

In Canada, both Betts (1997), who examined manufacturing, and Gera, Gu and Lin (1999), who focused on both the manufacturing and service sectors (1981-94), 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 respectively 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 ICT 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 1,080 firms and tested the relation between new technologies and upskilling, using the GMM estimator for dynamic panels. With a dummy on the introduction of “technological capital” used as the technological variable, the SBTC hypothesis was confirmed, while no significant effect emerged 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 confirmed by Falk and Koebel (2003). Their empirical analysis indicated that the accumulation of office machinery and computer capital stock - in 35 German industries over the period 1978-94 - was a relevant factor contributing to the shift in labour demand towards highly skilled workers (university graduates).

Machin and Van Reenen (1998) studied the phenomenon beyond the national level. They set up a panel (at the manufacturing-sector level for 7 developed countries over the period 1973-89) 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 reorganisation processes 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, 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 throughout Europe, although with different intensities from country to country (see Aoki, 1986; Greenan and Guellec, 1994; OECD, 1999). It is impossible here to give a thorough summary of the vast amount of literature - whose basic intuitions can be traced back to 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):

- 1) 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 more involvement, responsibility and autonomy at the shopfloor level (see Brynjolfsson and Mendelson, 1993; Greenan, 1996a; Bresnahan, 1999).
- 2) Collective work: new working practices such as work teams and quality circles require collective efforts from the workforce (see Osterman, 1994).
- 3) Multi-tasking: workers are now required both to perform a greater variety of tasks within a given occupation and to rotate between 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 innovation. 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 manufacturing.

Obviously, organisational innovation practices such as those briefly described imply that the manufacturing workforce must be upskilled. Accordingly, the “skill biased organisational change” (SBOC) hypothesis has been put forward and tested<sup>5</sup>. For instance, Greenan and Guellec (1998), using a 1987 French survey on work organisation, found that organisational change -

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<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.

such as greater worker autonomy and increased communication among workers - were 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), comparing two panels of French and British firms, focused mainly on organisational change (measured with a dummy). The results, which supported the SBOC hypothesis, turned out 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 is more closely connected to organisational than to technological change.

## **2.3 Technological change associated with organisational change**

While 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 either in terms of

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

productivity or profitability (see Pavitt *et al.*, 1989; Milgrom and Roberts, 1990 and 1995; Black and Lynch, 2001<sup>7</sup>).

Indeed, new ICT technologies modify the way in which decisions are made 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 make delayering into a flatter organisation feasible, 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 increase in productivity, probably because of the special nature of information technology. As pointed out by Gibson (2002) in his study on computers and the wage structure in New Zealand, ICT is mostly a “general purpose technology” (GPT), whose major impact on the economy is not direct but occurs through a wide range of secondary innovations. As a consequence, introduction of a new GPT does not immediately coincide with a surge in productivity growth; at least as long as firms invest in developing these secondary innovations. This experimentation phase requires both workers that are skilled and workers who are “adaptable”, in the sense that they possess a combination of general knowledge and on-the-job experience that cannot be acquired through

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<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’s 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.

vocational and specific technical education but is learnt only from wide-ranging education and training.

The above theoretical considerations are supported by empirical evidence. For instance, on studying the 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 ICT technologies 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 in Hitt and Brynjolfsson (2002), and they confirm the close complementarity between ICT 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 ICT 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 (1987-94) 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.

### **3. Some results from Italian manufacturing**

In this section an empirical analysis of a sample of Italian manufacturing firms is presented, the purpose being to assess technological change and reorganisation as possible determinants of the skill bias in a medium-technology country.

Data are taken from a database of Italian manufacturing firms with no fewer than 11 employees. The 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 three 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<sup>11</sup>. With reference to skills, the MCC data permitted the 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 originally introduced by Kmenta (1967) to approximate the CES production function, and formally developed by Christensen *et al.*

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<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 remaining cases, two dummy controls indicating whether the firm declared takeovers or break-ups were included.

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



(1971 and 1973). The model used is in long differences (for a similar approach see Caroli and Van Reenen, 2001), thus both eliminating firms' fixed effects and avoiding possible problems of endogeneity (see Acemoglu, 1998)<sup>12</sup>. For our purposes, the most appropriate method for estimation is Zellner's (1962) seemingly unrelated regression (SUR), 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 (for a similar econometric approach applied to the empirical analysis of skill bias, see Machin *et al.*, 1996; Betts, 1997; Adams, 1999). In this context, in our joint econometric specification the dependent variables are the log of differences (1991-97) in WC and BC. The aim is to test the role of the two possible determinants of skill bias - measured as dummies which indicated the presence or absence of R&D expenditure and organisational change (ORG)<sup>13</sup> in the previous period 1989-91 - controlling for all contemporaneous determinants such as output

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<sup>11</sup> In 1997, the average size of firms in the sample is 350 employees (with a standard deviation of 609), the minimum firm size is 12 and the maximum is 5,000.

<sup>12</sup> It was not possible to use a dynamic panel structure, because - in the MCC database - some 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 three-year period).

<sup>13</sup> For R&D the question in the questionnaire was "whether the firm has carried out investments in R&D activity during the three years" and for ORG "whether the firm has carried out significant organisational changes in its structure". 192 firms out of 400 made investments in R&D, 167 implemented significant organisational changes and 93 carried out both R&D investments and organisational changes.

(sales), capital and labour costs (WC and BC wages) which could influence the causative link we want to study<sup>14</sup>.

Additional controls are included: three sector-fixed effects (sectors with high, medium and low technology)<sup>15</sup>, five firm's 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 1991-97.

Table 1 gives 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, although exhibiting the expected signs<sup>16</sup>. As a matter of fact, Italian manufacturing comprises a large fringe of family businesses – some of which are relatively large in size, such as most of those in our sample (see footnote 11 above) – either operating in traditional industries or below the technological frontier when active in advanced sectors. These typically family-run firms are characterised by direct family involvement in daily operations, more than one family member

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<sup>14</sup> Because the average annual wages of WC and BC workers were not provided by the MCC database, they were calculated by merging the MCC database with the INPS (Italian National Institute for Social Security) database. 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.

<sup>15</sup> According to OECD (1998); this control was found to be never significant and so was been dropped from the final estimates whose results are reported in Table 1.

<sup>16</sup> Neither 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 for other forms of technological change 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).

with significant management responsibility, and multiple generations involved. They are therefore devoid of the features that are distinctive of Berle and Means (1932) corporations, including separation of ownership and control, presence of professional managers that exercise (nearly) full control, etc. (see Burkart *et al.*, 2002). 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 R&D activities.

**< INSERT TABLE 1 >**

The ORG variable instead affects the demand for BC and WC with the expected signs and turns out to be significant in determining redundancy among the unskilled. This is consistent with a view of Italy that can be traced back to Fuà (1988), who stressed the importance of the so-called organisational-entrepreneurial factor in re-shaping the profile of those Italian firms not relying 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). This important result suggests a superadditive skill bias effect of reorganisation combined with technological change (see Section 2.3), and it is consistent with the findings summarised in Section 2.3 above. As a peculiarity of the Italian case, it should be noted that this joint effect seems to be unbalanced both in terms of statistical significance and the values of the coefficients. In other words, organisational change combined with new technologies mainly implies redundancy of blue-collar workers and only increases the demand for white-collar workers slightly.

#### **4. Policy implications**

The descriptive statistics of 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, workplace reorganisation appears to have favoured more skilled (or qualified) workers slightly, 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 are particularly exposed to labour-saving organisational and technological changes (see Freeman and Soete, 1994). Hence, policy makers should support holistic strategies at the level of the firm (on-the-job training aimed at transferring non-cognitive 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<sup>17</sup>.

Some of the literature on technological change suggests that workers are better off with general rather than vocational education, because their skills are in this case less likely to be

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<sup>17</sup> Organisation, technology and skills are the three angles of the black triangle explaining economic performance in Caroli (2001).

rendered obsolete by technological progress. Similarly, qualitative evidence arising from discussions with entrepreneurs and firm insiders points to increasing demand not only for cognitive skills such as those revealed by traditional measures of scholastic achievement, but also for “sociability”. These prescriptions are 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>18</sup>.

This policy implication appears to be consistent with the view of ICT as pervasive “general-purpose technologies” applicable across a wide range of functions and tasks (see Bresnahan and Trajtenberg, 1995; Freeman and Louçã, 2001). 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)<sup>19</sup>. According to this view,

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<sup>18</sup> For a similar opinion, see Steedman *et al.* (1991) and Caroli (2001). Indirect evidence of the unfulfilled need for more general knowledge at the intermediate and lower levels of the occupational structure is the use of graduates at the shopfloor level, see Mason (1996) and Mason and Finegold (1997).

<sup>19</sup> Among studies which consider skill bias in services as well in manufacturing see Autor *et al.* (1998); Gera *et al.* (1999); Mairesse *et al.* (2001); Falk and Koebel (2003). However, only a few studies have specifically investigated skill bias in service sectors (see, for instance, Kaiser, 2000 and Evangelista, 2000).

both technological change alone and any consequent organisational change require more general and adaptable skills rather than specific competencies. 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 at general content, models and methodologies rather than at specific technical competencies. According to Bresnahan (1999) and Bresnahan *et al.* (2002), general education should also embrace a number of “noncognitive” 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.

Indeed, this suggestion concerning education policy may apply to both the micro- and the macroeconomic level. For instance, in a recent paper analysing the skill bias in French manufacturing over the period 1984-1995, Maurin and Thesmar (2003) have found a clear tendency for jobs that can be programmed in advance to be replaced by ones that require constant adaptation to change. Once again, this makes the case for general rather than vocational/specific/technical education and training (see Nelson and Phelps, 1966)<sup>20</sup>.

Finally, and still at the aggregate level, 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

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<sup>20</sup> On this basis, Krueger and Kumar (2003a and 2003b) have put forward a theoretical macroeconomic model in which they show that European education policies favouring specialised education may have worked well in the 1960s and 1970s when technologies were more stable and European countries were involved in catching-up, but

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**

The recent theoretical and empirical literature has focused on the coevolution of technological and organisational change within firms. One implication of these studies is that skill upgrading is no longer a consequence of technological change alone, but is also an effect of the overall reorganisation of the firm, which in turn may be linked to technological change.

This paper has offered new evidence supporting the hypothesis of a superadditive effect of technological and organisational change on the skill composition of Italian manufacturing employment. In particular, it has shown *a)* that the alleged role of R&D alone in determining skill bias is not confirmed by econometric estimations, *b)* that significant organisational changes made by a firm to its structure and functions are major factors affecting skill composition, and *c)* that combining the R&D and the Organisation (ORG) variables yields higher and more significant coefficients, even in comparison with ORG in previous estimates. If such 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 at the expenses of technical/specific knowledge. The correlated hypothesis of general rather than vocational

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they may also have had a role in increasing the growth gap between Europe and the US during the 1980s and 1990s, when new ICT technologies emerged rapidly.

education as one of the factors positively affecting both firm's performance and aggregate economic growth paves the way for further research.



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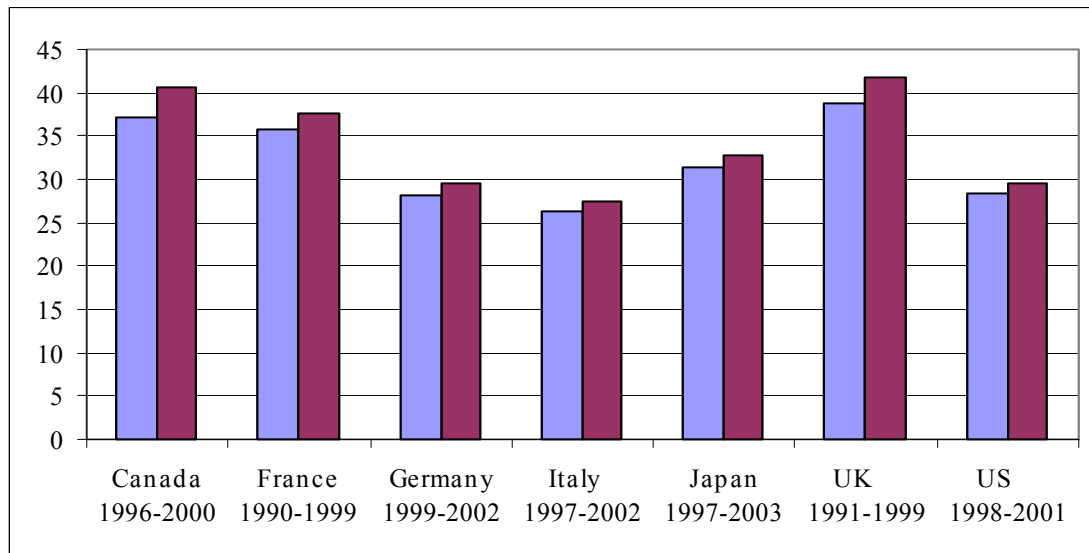
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**Figure 1. Shares (percentage values) of white-collar workers in manufacturing employment in the G-7 countries.**



### Sources

Canada: Based on Population Census, *Statistics Canada*; France: Based on Recensements de la Population, *INSEE*; Germany: Based on Employment Register, *IAB Germany*; Italy: Based on Sistema Informativo Excelsior, *Unioncamere*; Japan: Based on Labour Force Survey and Population Census (data include also the construction sector; 2003 data are relative to the month of June), *Statistics Bureau*; United Kingdom: Based on Labour Force Survey, *Office for National Statistics*; United States: Based on Population Census, *US Bureau of Labor Statistics*.

**Table 1. SUR estimates of changes in the demand for WC and BC between 1997-91**

	(1) dlWC	(2) dlBC	(3) dlWC	(4) dlBC	(5) dlWC	(6) dlBC
Constant	-0.17*** (2.72)	-0.14** (2.08)	0.15** (2.01)	0.02 (0.26)	0.16** (2.14)	0.003 (0.05)
Sales	0.32*** (5.77)	0.38*** (6.33)	0.31*** (5.64)	0.39*** (6.53)	0.31*** (5.49)	0.40*** (6.60)
Capital	0.04 (1.15)	0.09** (2.50)	0.04 (1.06)	0.10*** (2.63)	0.04 (1.09)	0.10*** (2.59)
Wages	-0.60*** (6.99)	-0.01 (0.06)	-0.59*** (6.95)	-0.01 (0.16)	-0.59*** (6.91)	-0.02 (0.17)
R&D	0.01 (0.28)	-0.02 (0.43)				
ORG			0.06 (1.49)	-0.08 (1.81)*		
ORG*R&D					0.08* (1.69)	-0.11** (2.00)
Fixed effects:						
TB	5.56* 25.45**	1.20 14.73***	5.87* 26.12***	1.11 12.47**	5.76* 26.93***	1.17 12.86**
Size						
R <sup>2</sup>	0.23	0.19	0.24	0.19	0.24	0.19
Observations	400	400	400	400	400	400

**Notes:**

- t-statistics in brackets: \* significant at 10%; \*\* significant at 5%, \*\*\* significant at 1%.
- R&D and ORG refer to the three-year period 1989-91; WC, BC, sales, capital and wages are all expressed as a difference of the logarithm (1997-91).
- With reference to the fixed effects (TB = takeovers and breakups; Size = five firm size classes) 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:  $\chi^2(1) = 74.143***$ ,  $\chi^2(1) = 73.147***$ ,  $\chi^2(1) = 72.784***$ .

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