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IS THERE SKILL-BIASED TECHNOLOGICAL CHANGE IN ITALIAN MANUFACTURING? EVIDENCE FROM FIRM-LEVEL DATA

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ABSTRACT:

The bulk of the literature on the Skill-Biased Technological Change (SBTC) hypothesis has focused on the US and the UK, while evidence on other countries is 'mixed'. We use firm-level data to test for the presence of SBTC in Italian manufacturing. The interest stems from the fact that Italy is a "late comer" country, suffers a gap in new technologies and has a 'rigid' labour market. We estimate employment-share equations using as a skill-ratio two alternative measures, the ratio between white collars and blue collars (WC/BC) and that between graduates and non-graduates (G/NG). We find an unconventional evidence supporting SBTC. First, with the most traditional indicator (WC/BC), a significant effect of R&D is only found when the latter is disaggregated by destination: SBTC mainly runs via process-oriented R&D. Instead, a significant impact of R&D on the skill-ratio is always uncovered with G/NG. Further disaggregations confirm that the impact of R&D is mainly due to incremental process-oriented activities. These results can be easily reconciled with the structural characteristics of Italian manufacturing, where traditional sectors and small and medium sized firms prevail, innovative activities are mainly incremental and the capacity to absorb skilled labour rather limited.

JEL CLASSIFICATION: J210, L600, O330.

KEYWORDS: Firm-level, ICT, Italy, Manufacturing, Skill-biased technological change, R&D.

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Introduction

Technological change has often been thought as implying a substantial modification in the composition of economic activity, and in the way the latter is organized.

Since the early Nineties, several contributions have investigated the causes of the upskilling trend in the composition of the labour force, focusing on a possible bias towards more skilled labour induced by technological capital. According to this hypothesis, new technologies raise the need for workers possessing new knowledge and abilities, and produce an asymmetric impact on hiring and firing of workers with different skill levels; moreover - as a complementary and reinforcing effect - low-skilled employees (or those having skills no longer in line with the new technologies) may become redundant and be substituted away. In both cases, at the aggregate level (either national or industry level) the resulting effect would be an increase in the ratio between skilled and unskilled employment (the skill-ratio, henceforth). This issue has a highly relevant policy-implication: those policies promoting technological innovation in a country could feed back on the labour market, raising the employability of high-skilled workers.

Despite the now abundant body of literature, data shortcomings and methodological difficulties are such that the Skill-Biased Technical Change (SBTC, henceforth) hypothesis still needs more refined tests. This is especially true for countries other than the US, such as the continental European ones. Italy, on which we shall focus our analysis, is an interesting case, since it stands as follower in the realm of R&D activities and the diffusion of ICT technologies.

The structure of the paper is as follows. In section 1 we present a brief discussion of the relevant literature along with an analysis of the main methodological problems still at the core of the SBTC debate. In section 2 we highlight some structural characteristics of the Italian economy, focusing on the scientific and technological level of the country. In section 3, we briefly introduce the dataset used to frame our empirical test of the SBTC hypothesis for Italy, going through a preliminary overview of its main characteristics. Section 4 discusses our empirical specification, together with the main econometric issues. Section 5 presents the main results. The final section concludes.

1. Literature Review

1.1. The debate on SBTC

A large body of literature has addressed the question of the rising importance of skilled labour within the total workforce employed in the economy. Acemoglu (2002) reviews the main findings of this debate, highlighting some stylized facts. First of all, the increase of skilled employment took place both in absolute terms and as a ratio over the unskilled one. Several countries also displayed an analogous increase of the wage bill share of skilled labour. Furthermore, the increase of the skilled wage bill share was not just the natural outcome of its faster dynamics in terms of number of workers, but also reflected a relative price change: the unit wage of skilled labour, relatively to the unskilled, rose. At least, this is true for the US since the early Eighties, while for other countries the relative wage dynamics was less pronounced.

On the supply side of the labour market one observes that, whatever the skill measure (the level of education or the white/blue collars classification), the supply of skilled labour increased almost monotonically in the most industrialized countries, at least since the Second World War aftermath.

Now, after having analyzed these stylized facts within a traditional framework of competitive market adjustment, one should conclude, as nicely exemplified by Machin (2001), that the magnitude of the shift of the relative demand for skilled labour has been greater than its supply, yielding a new equilibrium characterized by a higher (relative) wage and a higher (relative) share of skilled employment. However, at this point one should also explain the determinants of this purported demand shift.

Several explanations have been proposed in the literature. For the sake of synthesis, we can draw a broad classification distinguishing between two main streams of contributions, the trade-based explanation and the technology-based explanation (or SBTC).

The trade-based explanation focuses on the dynamics of world trade. In short, the most advanced economies would specialize in modern industries producing high-technology products and services, while loosing the more traditional low-technology and labour-intensive activities. This transformation would explain the rise in the relative demand for skilled workers and the increase in the skilled workers' wage bill share. Contributions stressing the trade-based explanation include Lawrence and Slaughter (1993), Wood (1994), Borjas and Ramey (1995) and Haskel and Slaughter (2001) among others.

The SBTC hypothesis, whose seminal contributions date back to the works of Bound and Johnson (1992) and Berman et al. (1994), has a more microeconomic flavour and is based on the concept of complementarity between capital, new technology and skilled labour, originally proposed by Nelson and Phelps (1966) and Griliches (1969). The SBTC hypothesis has attracted a large consensus and has prevailed as the main explanation for the upskilling trend of the workforce[1].

Basically, the purported complementarity between new capital and skilled labour states that producing and adopting new, technologically advanced (and knowledge-intensive) capital requires the availability of skilled labour, whose productivity is thereby increased, with respect to that of the unskilled one ("pars construens"). However, the

[1] More details on the extensive debate on upskilling can be found in the reviews of Chennells and van Reenen (1999), Acemoglu (2002) and Card and DiNardo (2002).

SBTC has also a "pars destruens": in fact, since workers' education and training activities are costly and lengthy processes, a skill-mismatch between supply and demand of labour may imply the definitive dismissal of those workers who are more difficult to retrain.

The SBTC contributions do not ignore the possible influence of other explanatory factors, such as changes in trade flows[2]. Moreover, the originary SBTC approach has recently transformed into a less deterministic perspective, enlarged to accommodate other complementary explanatory factors. A common finding of the more recent literature is that new technologies are typically associated to organizational changes, hereby leading to a higher demand for skilled workers. The underlying rationale for this evidence would be that new technologies, such as ICT, promise substantial productivity gains, but their effective implementation takes time and becomes productive only if the workforce is properly educated and trained; so, the successful adoption of new technology requires a virtuous co-evolution between technological change, organizational change and the availability of skilled workforce (on this point, see also Brynjolfsson and Hitt, 2003). For instance, Bresnahan et al. (2002) study a panel of around 300 large US firms over the 1987-94 period (industry and services), with detailed data on IT capital, skills (by education and position) and a list of organizational practices (team-based work, self-managing teams, distribution of decision authority, etc.). The regression analysis is carried out both with factor demand and productivity equations. As a main result, a significant relation of complementarity emerges between new technology (IT investment and the introduction of new products and services), organizational change and human capital: firms investing in these areas tend to employ a higher share of skilled labour. In particular, although new technology maintains a logical "prior" (IT-enabled organizational change), when it is accompanied by complementary organizational change it exerts a more relevant impact on the demand for skilled labour. Other contributions propose a stronger version of the skill biased organizational view (SBOC, henceforth), arguing that organizational change in itself can be the main explanatory variable, independently of technological change. This is the case of Caroli and van Reenen (2001), who adopt an OLS long-difference specification of the wage bill share equation and find that the (lagged) dummy for organizational change significantly explains the skill bias, particularly in terms of a reduction of the demand for the unskilled workers, both in a sample of French (in 1992-96) and British firms (in 1984-90).

Moreover, SBTC has recently been investigated in a more appropriate time horizon. In fact, in previous literature the length of the time period examined may have not be suitable to capture the long-run effects of new technology adoption. Consequently, if the big-

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[2] The seminal contribution of Berman et al. (1994), for example, found that in the US for the period 1959-1987 the variation of the non-production labour share was mainly accounted for by technological variables, and only negligibly by trade or defence public procurement. More recently, Morrison and Siegel (2001) have further explored the interaction effects among trade and technology. Their main findings are that trade induces computerization, exacerbating the effects that the latter autonomously plays on labour demand. However, the direct effects played by computerization are far more important and robust than those directly played by trade and outsourcing.

ger employment effects of technology materialise later, one could have an understated measure of the upskilling phenomenon. Short run and long run effects of IT have been tested by Chun (2003), who estimates a standard labour cost share equation on a sample of 56 US (industry and service) private sectors over 1960-96. The various specifications (in differences with pooled regressions) include both an index of "average age of the IT capital" (adoption effect) and the stock of IT capital (use effect), together with R&D intensity, relative wages, industry and time dummies. First, the results strongly support the SBTC hypothesis: IT is complementarily associated to (college) educated workers. Further, decomposing the overall contribution of IT to upskilling during 1970-96 shows that the major portion of the IT effect on the upskilling acceleration is accounted for by IT use. So, the initial effect on skilled labour stemming from the adoption of new technology is a (largely) incomplete assessment of its overall upskilling potential.

Finally, while originary contributions on SBTC were mostly based on industry-level data, more recent works have focused on firm-level data. Indeed, the industry-level analysis typically yields a synthesis of different (and possibly counteracting) tendencies: not only SBTC, but also an industry's demographic dynamics (entry, exit and growth of firms, together with their internal re-allocation of output), or changes in the degree of integration (both horizontal and vertical) of a sector.

Consequently, SBTC can be more precisely investigated if the industry-level analysis is complemented by a firm-level one. This is particularly useful for countries other than the US and the UK. Indeed, as better explained in the next section, (continental) European countries are technological followers with respect to the US, and display labour market characteristics that may shape differently the SBTC phenomenon. This caveat is particularly important for Italy, on which we will focus our econometric analysis.

1.2. The European experience and the Italian case

European countries (still) have a relevant gap in new technologies with respect to the US, as shown by two representative indicators, R&D activities and ICT diffusion. Concerning the first, in 2001 the overall (public and private) R&D expenditure over GDP was respectively 2.8% for the US and 1.9% for the European average (EU-15, henceforth); further, private R&D expenditure on industrial value added was respectively 2.8% and 1.8%. Relatedly, in 2000 US industrial firms employed 10.2 researchers every 1000 industrial workers, while EU ones only 4.1 (OECD, 2003b).

Concerning the second indicator, in 2001 IT expenditure over GDP was 5.45% for the US and 3.45% for the EU average, while IT per capita spending was respectively 1,522 and 745 euros. Moreover, other indicators signal that the European gap affects both firms and households: for example, the number of business PCs for 100 white collars (WC) workers is 138 for US and 77 for the EU, while the gap widens if we consider the number of PCs per 100 units of population (EITO, 2003, p. 76).

Finally, it is widely known that US and EU differ in labour market institutions. US is typically considered to have a flexible labour market, with weak hiring and firing regulation and a lower standard of public social security. Further, the US wage setting system is conventionally seen as competitive and not significantly constrained by institutions, such as "minimum wage" legislation or centralised setting schemes. Europe, instead, with some significant exceptions (such as the UK), has a more rigid labour market: firing is subject to a rather complex procedure and the wage setting system is more centralised and subject to "minimum wage" standards; "on the job training" is often publicly subsidised and the average degree of unionisation of the labour force is higher than in US.

These elements are not always carefully considered in the literature focusing on upskilling, while they are an essential part of the story, especially in cross-country comparative studies. Indeed, the European delay in R&D activities and ICT adoption and its different labour market institutions could explain some features of the EU employment patterns - especially why in the past in selected European countries the evidence in favour of SBTC was not robust (see further below on this point).

In particular, these elements should be considered in the light of the complexity of the relation between technology and employment. Previous contributions have stressed that to fully reap the benefits of a new technological paradigm a country must undergo a complex and lengthy process of structural adjustment, which affects both the techno-economic and the socio-institutional spheres (for e.g., Freeman 1987, David, 1990, Petit and Soete, 2001). In fact, the benefits expected from a new technology generally materialise with a delay, well after the initial adoption phase, because of the discontinuous nature (across time and space) of innovative activities and related cycles of investment. For example, R&D activities mainly respond to (sectorally-different) technological opportunities, and are principally carried out by big and medium-sized firms. Contrary, ICT are more pervasive technologies (Helpman, 1998); however, still in the Eighties and early-Nineties, most ICT solutions had rigid architectures (as in the case of mainframes) and presented high barriers to adoption (due to scale and learning effects), which considerably slowed down their diffusion and effective implementation. Still nowadays, as suggested by Brynjolfsson and Hitt (2003), the productivity potential of ICT fully unfolds only after a virtuous cycle between (product and process) innovation, complementary organizational changes and the availability of a skilled and properly trained workforce.

Consequently, in a given country the upskilling trend of employment could be delayed, or unfold unbalanced across sectors, reflecting the sectoral composition of the economy and its technological level (see section 2 on this point). Finally, the skill bias could be associated only to a sub-set of technologies, which are particularly challenging and skill-demanding.

These preliminary considerations guide us through the puzzling evidence on SBTC available for most European countries. First, we can draw a distinction between industry-level and firm level studies. At the industry-level, the SBTC hypothesis has been confirmed in those studies which compare the US experience with the EU one. Machin and van Reenen (1998) study a panel of 7 countries (Denmark, France, Germany, Japan, Sweden, UK, US) over various time intervals (within the period 1973-89) with 15 manufacturing sectors. The principal indicator of skill they use is the wage bill share of white collars; further, for subsets of countries, they also use the employment share of white collars and the graduates share of employment. The SBTC hypothesis is confirmed: the regression coefficient of R&D intensity (calculated over value added) is positive and significant.

In other words, the sectors which invested more in R&D, experienced a stronger upskilling trend in the workforce. Moreover, the above positive relation appears to be causal and rather robust, since it is generalised to 7 countries and emerges with different specifications, controls (including that for endogeneity) and technological variables (also with ICT intensity). Finally, also the inclusion of trade-related variables does not modify the results[3].

In other works, focused on individual European countries, the evidence in favour of SBTC is less straightforward. While for the UK the results are generally similar to those found for the US, with results confirming the SBTC hypothesis (see, for example, Machin, 1996), for continental European countries the evidence is mixed.

For France, Goux and Maurin (2000) study the determinants of the labour demand using sectoral surveys of the French labour force, for both manufacturing and the whole economy, over the period 1970-93. They have data on wage and workers' educational levels by industry, together with data on the diffusion of computers and other micro-electronic technologies. It emerges that new technologies (computers and automation technologies) in France have not played a relevant role in the skilled labour demand (workers with a secondary school or university degree). Instead, the reduction of the unskilled share of the employment is mainly explained by domestic demand changes, and to a lesser extent by the relative fall in the labour cost of the skilled.

A partially different conclusion is reached for France with aggregate firm-level data by Maurin and Thesmar (2004). They analyse the patterns of high-skill and low-skill jobs across five categories of activities (conception/development, logistics/transportation, administration, production and sales/marketing), exploiting a large panel of French manufacturing firms, over the period 1984-95. Then, they relate the patterns of skills and use of new technologies (personal computers and NC machine tools) employing a shift and share analysis and estimating aggregate skill-ratio and labour cost equations. On overall, a significant pattern of SBTC is found. However, its occurrence varies across tasks and functions. First, SBTC materializes mainly as an upskilling trend connected to the rising importance of non-programmable cognitive activities, such as conception/development

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[3] In a related work, with a "shift and share" analysis for a larger set of countries, Berman et al. (1998, p.1257) verify that the aggregate upskilling trend present in the 70's and 80's is mainly a "within" phenomenon, since the share of the latter on average accounts respectively for 84.3% and 91.5% of the increase of the share of non-production workers registered in the two decades; the remaining "between" share, which reflects the portion of the upskilling trend explained by variations in trade flows and domestic demand, is well inferior.

and sales/marketing ("between activities" shift). These activities require increasingly more skilled personnel than activities easy-to-programme (such as administration and production), which, thanks to new technologies, can be performed by less skilled personnel (either white or blue collars). Second, but less relevant in size, there is also a "within activities" shift induced by new technologies, which substitutes skilled workers for less skilled ones within activities (mostly in logistics/transportation and production).

The analysis of Maurin and Thesmar (2004) disentangles some aspects of the complex relationship existing between technology and skill-upgrading: as a matter of fact, this relationship should be studied using a comprehensive list of proxies for technology (for example, not only R&D or ICT, but both) and a multidimensional one for workers' skills (not only job qualification – as in WC/BC dichotomy - but also educational level and firm's function). When the relevant data lack, the analysis is incomplete since the SBTC hypothesis is not fully explored across all its possible combinations.

Concerning Italy, the empirical literature on SBTC is limited and severely constrained by data availability, particularly binding at the sectoral level. For instance, Bella and Quintieri (2000) test the role of trade changes (and implicitly technology) on employment and wages in a panel of 71 manufacturing industries during 1975-89. First, the authors find that labour market adjustments to demand shocks in Italy occur via employment changes, while the wage adjustments are negligible, especially for BC. Moreover, although the authors lack a proper technological variable, the evidence seems to suggest that the loss in (total) employment over 1976-89 is explained primarily by technical change and wage growth, more than trade.

Additional research is needed for Italy also at the firm-level. A few tests have been proposed, with diverging results. Casavola et al. (1996) matched two different datasets, the INPS (providing social security data) and the CADS (a dataset on companies' accounts developed by the banking sector): they have data on employment (separately for WC and BC workers, together with their average earnings), industry, age, location and balance sheets. The resulting panel of 35,174 firms, representing the non-agricultural private sector for the period 1986-90, enables the authors to assess both the wage and the employment dynamics, and to relate them to technological change, measured as firms' "intangible assets" (the ratio of intangible capital - software, patents, R&D expenditures and other intangible assets - on total capital). Despite some doubts on the adequacy of this measure of technology[4], the results confirm the SBTC hypothesis.

First, the descriptive analysis uncovers an upskilling trend, with the WC wage bill share increasing over the period. Second, the overall variance of earnings is mainly explained by a within phenomenon, and only residually (less than 30%) by a between (WC-BC)

[4] In fact, the results could be partly influenced by the fact that the variable "intangible assets" is too largely defined, since it includes other not-strictly technological items (such as business goodwill from mergers, other financial assets, etc.), which can however be correlated with the skill variables.

effect. Moreover, the shift and share analysis highlights that the within effect is systematically larger for the WC group and that, over time, the within dispersion of WC workers grows particularly among the most technologically advanced firms.

The causal explanation of this evidence is further refined with regression analysis (with cross-section and fixed effects panel estimations), with "intangible capital", industry and location dummies and size (number of workers) as explanatory variables. In the cross-section, a positive impact of technology both on the skill and the wage-ratio emerges[5]. This relation is mainly driven by employment share changes, supporting the view of the "wage inflexibility" and the adjustment via employment changes taking place in the Italian labour market (as in Bella and Quintieri, 2000). The panel specification yields similar results and shows a limited evidence of a wage premium connected to the use of new technologies. The lack of a relevant wage premium is explained by the authors with the occurrence of a contemporary increase in the supply of skilled labour, with the traditional inflexibility of the Italian centralized wage setting system, and with other institutional factors.[6]

More recently, another series of contributions has tackled the SBTC debate for Italy using the Mediocredito Centrale dataset, representative of manufacturing. Piva and Vivarelli (2002, 2004) focuse on a panel of 488 firms responding to 3 three-year waves of the survey (1989-91, 1992-94, 1995-97) and estimates a labour demand equation where labour is the only variable cost and capital and technology are quasi-fixed factors. In particular, Piva and Vivarelli (2002) use a long difference specification where the WC/BC ratio is regressed on output (sales), net capital and WC wages (all in differences over 1991-97), together with additional controls. Since the early editions of the dataset did not provide quantitative indicators for technology, organizational change and globalization, the authors need to rely on a series of dummies[7], lagged to the period 1989-91. The results show that only the dummy for organizational change (in particular, that occurring at the shop floor) is significantly related to the skill ratio, in a positive way.

In a closely related paper, Piva and Vivarelli (2004) use a Seemingly Unrelated Regressions (SUR) approach, which allows to distinguish the potentially different dynamics affecting WC and BC workers. A basic descriptive evidence is that in the sample no upskilling trend occurred during 1991-97, but rather a deskilling one: the average WC/BC ratio fell by 8%, and this trend affected also R&D-performing firms. A few

[5] In addition to the skill (WC/BC) ratio and the wage bill ratio, other specifications are tested, including as dependent variables the BC and WC earnings (separately), and the ratio between (unit) wages.

[6] Unions have a much more important role in the Italian wage-setting system with respect to the US and UK ones, to which most of the existing literature on the SBTC refers. According to a ranking made by the OECD (2004) Italy ranks 6th, the UK 18th and the US 24th in decreasing order of collective bargaining coverage in 2000. Moreover, while in the US and UK bargaining takes place at plant level, in Italy it is predominant a combination of industry and company/plant level bargaining (OECD 2004, p. 151), so the system is more centralised.

[7] In particular, technology is represented by a dummy of "R&D activity carried out in 1989-91". Obviously, dummies possess a loose informative power, since they do not capture R&D intensity.

facts emerge from the regression analysis. First, the coefficients of the traditional explanatory variables of labour demand are significant with the expected signs: in particular, wages are negatively related to both WC and BC. Second, neither technology (occurrence of R&D activities) nor globalization seem to matter for the skill-ratio. However, the dummy for organizational change is positive and significant: in particular, the SUR estimation uncovers that its impact is positive (but not significant) for WC and negative and significant for BC. Consequently, the authors conclude that for Italy the evidence available points more to the SBOC than the SBTC hypothesis.

To summarize, for European countries as a whole the evidence in favour of SBTC is less straightforward than for US. However, several considerations lead to think that this puzzling evidence can be coherently reconciled. We reviewed the possible role played by a time-lag and a dynamic path of SBTC, the lack of harmonised data, the likely bias implicit in qualitative measures of technological change and the role of country-specific characteristics.

In particular, concerning Italy, initial evidence in favour of SBTC has not been confirmed in more recent contributions. We believe that this conflicting evidence is mainly rooted on methodological reasons. Technological change is a multi-faced phenomenon, requesting appropriate proxies and a suitable time-period of analysis. Moreover, the skill-bias might not be easily captured by traditional indicators (as with the WC-BC skill ratio), which are likely to under-perform in the case of a generalised upskilling trend affecting both non-production and production workers; in addition, occupation-based indicators (as the WC-BC) reflect more sector-specific patterns than those based on educational attainment (on this point, see also Chun, 2003). Finally, the country-specific features (labour market institutions, manufacturing composition) of the sample studied should be also taken into account.

2. Technology and Labour Demand in Italian Firms

Italy is a "late comer" country which followed a development path qualitatively different from other similar European countries such as the UK, Germany and France. A large part of manufacturing is still today accounted for by traditional (basically Food-Beverages, Textiles, Clothing, Leather-Shoes, and Furniture - accounting for 36.2% of manufacturing employment in 2000) and metal-mechanical sectors (Metals and metal products, Machinery and Equipment - equal to 25.6%); high-tech sectors account instead for a tiny share – only 9.3% (ISTAT, 2003). The relatively large Italian share in the first two groups of sectors[8] is a stylised and persistent character of the Italian model of specialization, particularly based on low and medium-technology sectors. These sectors are the core of the NEC (North-East-Centre) model of development (Fuà, 1983,

[8] Comparatively, the weight of these two groups is inferior in the other main European countries and in the US: for example, in the latter, the corresponding percentages in 2000 are 12.6% for traditional sectors and 22.4% for metal-mechanics; conversely, US has a 14.4% of employment in high-tech sectors (OECD, 2003a).

Pyke et al., 1990) which is characterised by local agglomerations of industrial activities (industrial districts) populated by small and medium-sized enterprises (SME); moreover, this model of industrial organization has spread throughout the country, also among science and scale-intensive sectors.

These structural characteristics profoundly influence industrial innovative activities. Various studies have shown that incremental (either product or process) innovations are the typical innovative activity of Italian firms (ISTAT 1995a, Santarelli and Sterlacchini, 1994, Sterlacchini, 1998). In detail, technological innovations in traditional sectors mainly consist of adoption of new capital goods, prevailing both in terms of innovative expenditures and share of turnover affected. Second, traditional firms carry out design, pre-production and marketing activities (often conducted in partnership with the network of sub-contractors), while formal (intra-muros) R&D is relatively less important or not performed at all. R&D activities are more frequent among metal-mechanical firms (especially as Development), but rarely they come first in the ranking of the expenditures devoted to innovation.

TABLE 1. R&D INTENSITY (ON VALUE ADDED) IN MANUFACTURING

	Italy		US	
	1995	2000	1995	2000
Food products, beverages and tobacco	0.35	0.34	1.15	1.07
Textiles, textile products, leather and footwear	0.07	0.05	0.69	0.51
Wood, paper, printing, publishing	0.11	0.09	1.10*	1.57
Chemical, rubber, plastics and fuel products	3.04	3.26	9.13	9.05
Chemicals excluding pharmaceuticals	2.50	2.76	6.89	7.95
Pharmaceuticals	9.73	6.98	23.51	20.19
Other non-metallic mineral products	0.17	0.11	1.38	2.18
Basic metals	0.65	0.29	1.12	1.24
Fabricated metal products, except machinery and equipment	0.36	0.17	1.17	1.77
Machinery and equipment, instruments and transport equipment	6.21	5.69	16.30	16.42
Machinery and equipment, n.e.c.	1.34	1.65	4.63	5.51
Office, accounting and computing machinery	24.47	8.62	28.94	30.70
Electrical machinery and apparatus, n.e.c.	2.88	1.45	8.86	9.62
Radio, television and communication equipment	20.82	18.46	15.14	18.56
Medical, precision and optical instruments	3.20	3.46	25.39	30.21
Motor vehicles, trailers and semi-trailers	10.35	11.14	15.27	15.43
Other transport equipment	14.58	10.83	36.56	17.51
Aircraft and spacecraft	29.38	24.42	45.73	20.76
Furniture; manufacturing n.e.c.	0.25	0.12	-	-
TOTAL MANUFACTURING	2.21	2.15	8.09	8.52

* = *Includes R&D in Furniture.*
Source: *our computations on OECD (2002, 2003a).*

As a result, in the aggregate, the average Italian R&D intensity in manufacturing is quite low (2.1%, see Table 1), well inferior to that of the US technological leader (8.5%). However, the aggregate figure for Italy is not only due to the (previously described) composition effect, but also stems from lower sectoral R&D intensities: in other words, in a given sector, Italian firms invest in formal R&D much less than the US counterparts. First of all, this is true for R&D intensive sectors, like Chemicals (and particularly Pharmaceuticals: 7% versus 20%), Office Machinery, Medical instruments, and Motor vehicles. Second, it also happens in medium and low-tech sectors, such as (non-electrical) Machinery and equipment and most of traditional sectors.

Consequently, since manufacturing R&D represents the dominant share of a country private R&D effort, Italy turns out to be a low performer of private and total R&D, scoring below the EU average (Table 2). Moreover, the overall R&D effort of Italy has weakened during the Nineties, as also reflected in the R&D employment figures. Concerning the latter, the Italian gap is particularly big in R&D researchers - the most skilled portion of R&D employees (in 2000, Italian firms employed only 1.6 units, while EU on average 4.1 and US 10.2 – Table 2); but it is also relevant in total R&D employees, where the Italian share is less than 50% of the European one.

TABLE 2. R&D INDICATORS

	1981	1985	1990	1995	2000
Total R&D/GDP (%)					
US*	2.34	2.8	2.7	2.5	2.7
EU	1.69	1.9	1.9	1.8	1.9
Italy	0.88	1.1	1.3	1.0	1.1
Private R&D/GDP (%)					
US*	2.25	2.76	2.7	2.56	2.77
EU	1.44	1.66	1.78	1.61	1.77
Italy	0.64	0.84	1.04	0.74	0.75
R&D researchers every 1000 workers in industrial firms					
US	6.6	8.1	8.6	8.6	10.2
EU	2.3	2.8	-	3.5	4.1
Italy	1.2	1.5	1.9	1.7	1.6
R&D employees every 1000 workers in industrial firms					
EU	7	7.6	-	7.7	8.1
Italy	3	3.4	4	3.8	3.8

* = *Value understated, since it does not include most of expenditures in capital goods.*
Source: *our computations on OECD (2003b).*

Finally, Table 3 shows the series of yearly ICT national investment, expressed as intensity over GDP (both measured in constant terms to reflect quality and price changes). As a main evidence, we notice that the Italian ICT intensity, although increasing over time, falls well behind the EU average: still in 2000, the Italian intensity accounts for only 70% of the EU one (the distance with the US leader being even wider).

TABLE 3. ICT TOTAL INVESTMENT ON GDP

	1980	1985	1990	1995	1996	1997	1998	1999	2000
US	1.23	1.96	2.43	3.66	4.26	5.05	6.08	7.08	7.85
EU-14	0.65	1.22	1.95	2.64	3.09	3.58	4.58	5.39	6.21
Italy	0.58	0.93	1.60	1.99	2.30	2.74	3.18	3.77	4.28

***Source:** our computations on Groningen G&D Centre data (http://www.ggdc.net/index-dseries.html#top) for ICT investment and OECD (2003a) for GDP in constant terms.*

The low technological profile of the Italian economy does not appear to be conducive to a sustained absorptive capacity of highly skilled individuals (particularly, of graduates). Since comprehensive data on employment by education and sector lack for Italy, this statement cannot be rigorously and comparatively proved; however, a series of heterogeneous studies validates our conjecture.

First of all, also economic chronicles have recently been reporting about a "brain drain" phenomenon affecting Italy[9], which can be related to an increasing difficulty of absorption of graduates by the Italian labour market, although it is characterised by a lower share of secondary and tertiary educated people, with respect to the OECD average.

Second, recent surveys on graduates, like that run by the Italian national institute of statistics (ISTAT 1995b) and the IPLAM survey of Staffolani and Sterlacchini (2001), found that a large share of graduates remain unemployed for a long time or, if employed, earn a low salary. The IPLAM survey, monitoring the labour market outcomes of people getting an university degree from the universities of the Marche Region, is particular interesting because it provides a representative example of the employment opportunities in the NEC area. Staffolani and Sterlacchini (2001) found a certain mismatch between educational contents and skills demanded by firms. In particular, non technical and non scientific degrees are in excess supply, while technical and scientific curricula, although are in high demand, often are not tailored at the skill needs of SME. The likely outcome is an over-education one, since 40% of people employed 5 years after graduation have a job profile for which the university degree was unnecessary (see Staffolani and Sterlacchini, 2001, p. 216).

Third, this picture seems to be valid for the whole country (including more "fordist-like" sectors and geographic areas). The skill-mismatch is probably the result of both individual educational choices, too focused on curricula in excess supply, and the specific and mainly applied skills demand emerging from a dominant part of the Italian economy. Bottone and Marignetti (2000) support this view analysing the evidence of the

[9] An original contribution on "brain drain" for Italy is offered by Becker et al. (2004). They found that during the Nineties the human capital of Italian emigrants has significantly increased. In particular, since the mid-Nineties, the share of college graduates among emigrants from Italy has surpassed the graduate portion of the residents in Italy. The worrying phenomenon of the "brain drain" seems to be unique to Italy, while other comparable European countries experience rather a "brain exchange".

Excelsior dataset, which gathers data on the firms' prospective labour demand[10]. They found that, of the labour inflows forecasted for 1997-98, a large share (43%) is represented by (specialised) blue collars (for which a university degree is superfluous and a higher secondary education not always needed); 46% is accounted for by white collars jobs, for which an intermediate/below-intermediate (secondary level) level of education is typically required; finally, only 6% of jobs are targeted at high skilled people.

To conclude, in the light of this evidence, there seems to be little room for a robust and generalised SBTC trend for Italy, as detected instead for other developed countries. Consequently, also the indeterminacy stemming from previous studies can be more fruitfully understood. The following analysis is devoted to a reassessment of the manufacturing case, for the most recent period.

3. Data Description

In our empirical analysis we use data from the Survey of Italian Manufacturing (*Indagine sulle imprese manifatturiere*, SIM hereafter) managed by the Capitalia Banking Group (formerly Mediocredito Centrale). The survey gathers information on a representative sample of firms with 11-500 employees and on all firms with more than 500 employees[11]. The survey is repeated over time at three-year intervals and in each wave a part of the sample is fixed while the other part is completely renewed every time (rotating panel). This helps to analyse both variations over time for the firms observed in different waves and the structural changes of the Italian economy, for the part of the sample varying across waves.

In our analysis, we use a panel of firms appearing in both the 1995-1997 and the 1998-2000 waves. The two waves gather information on 4,497 and 4,680 firms, respectively. The firms appearing in both waves are 1,297. However, our estimation samples will include a lower number of observations because of missing data.

In this section we compare some descriptive statistics for the panel (1995-1997 values) and the 1995-1997 wave in order to assess the representativeness of the former. Some descriptive statistics are reported in Table 4. The distribution of firms by number of employees and geographic location is very similar in the panel and the 1995-1997 wave, although medium size firms are slightly over-represented in the panel. The average amount of sales[12] and the average capital stock are lower in the panel. The value added per worker is slightly higher in the 1995-97 wave than in the panel, but the difference is not huge. The average amount of total investments per worker is lower in the panel. In

[10] In this survey firms are asked about the expected number of workers needed, disaggregated by jobs and skills. Most of the private sectors are covered (excluding Agriculture). Public sectors (such as Public Administration, Health, Education, etc.) are also excluded.

[11] See Mediocredito Centrale (1999) and Capitalia (2002) for the methodological aspects of the survey.

[12] All values are expressed in millions of current Italian lira.

the panel, Supplier Dominated sectors are over-represented and Scale Intensive sectors under-represented, like the distribution by the Pavitt[13] classification shows. The ratio between ICT expenditures and sales is 0.3% both in the 1995-1997 and in the panel. Also the ratio of R&D expenditures on sales is the same in the two samples (0.5% in both cases).

In summary, the panel can be considered as fairly representative of the 1995-1997 wave over several dimensions (firm geographical location, firm size, value added per worker, ICT and R&D intensities). However, we notice that the sample of firms in the panel has a relatively smaller average capital stock and sales with respect to the firms included in the 1995-1997 wave.

TABLE 4. SUMMARY STATISTICS FOR THE 1995-1997 WAVE AND THE PANEL (SURVEY OF ITALIAN MANUFACTURING DATA)

Variable	1995-97 wave	Panel
Size		
11-20 employees (%)	26	23
21-50 employees (%)	38	43
51-250 employees (%)	26	25
251-500 employees (%)	6	6
> 500 employees (%)	4	4
Geographic area		
North-West (%)	40	42
North-East (%)	30	30
Centre (%)	17	17
South and Islands (%)	13	11
Pavitt sector		
Supplier Dominated (%)	42	49
Scale Intensive (%)	28	19
Specialized Supplier (%)	26	29
Science Based (%)	5	3
Average value added per worker[a]		
1995	93.95	90.08
1996	86.70	83.28
1997	87.86	85.46
Average sales[a]		
1995	42793.64	35056.39
1996	43803.77	35717.51
1997	47652.55	38558.57
Average capital stock[a]		
1995	10628.36	9702.77
1996	9167.71	7909.67
1997	9642.45	7920.50

[13] See Pavitt (1984).

TABLE 4. CONTINUED

Variable	1995-97 wave	Panel
Average investiment per worker[a]		
1995	17.63	16.80
1996	16.94	16.22
1997	18.50	16.66
Average (firms' ICT expenditures/Sales)%		
1995-1997	0.30	0.30
Average (firms R&D expenditures/Sales)%		
1995-1997	0.50	0.50

Note: [a] *Millions of current Italian lira.*
Source: *our computations on SIM.*

4. ECONOMETRIC METHODOLOGY

The SIM does not provide data on labour costs or wages by level of job qualification or education, and therefore we are not able to estimate wage bill-share equations. Machin and van Reenen (1998) used the same type of specification derived analytically for wage-bill-share equations also in the estimation of employment-share equations, i.e. equations explaining the variation of the share of skilled workers on total employment[14]. An alternative indicator of skill-bias which has been used in the economic literature is the ratio between the number of skilled and unskilled workers that we call the skill-ratio (see for instance Casavola et al. 1996, Piva and Vivarelli, 2002, Maurin and Thesmar, 2004). The latter is the indicator that we use in the current paper[15]. In this context SBTC is defined as an increase in the ratio between non-production (or white collars) and production workers (or blue collars) due to an increase in the stock of technology that firms use[16]. In our specification the skill-ratio (SR) depends on the tangible capital stock K (in natural logarithms), the amount of sales Y (in natural logarithms)[17], the wage ratio between skilled (S) and unskilled (U) workers W^S/W^U (in natural logarithms), some proxies for a firm's degree of 'technological intensity' or stock of 'technological capital' (TECH) and a firm specific fixed effect u_i constant over time:

$$SR_{it} = \phi + kt + \alpha \ln(K_{it}) + \beta \ln(Y_{it}) + \gamma TECH_{it} + \delta \ln(W_{it}^S / W_{it}^U) + u_i + \varepsilon_{it} \quad (1)$$

[14] Despite the fact that this specification has a rigorous analytical derivation only in the case of wage-bill-share equations.

[15] We use this indicator since it has been used in most of the previous work related to Italy, reviewed in section 2.

[16] However, in the SIM data set blue collars only include manual workers while technicians are included among the white collars.

[17] Sales are evaluated in millions of 1995 Italian lira.

where i and t are subscripts for firms and time, respectively, ϕ is a constant, kt is a common trend in skill bias due to technological change and ε_{it} is a random error term. In this specification capital stock and technology are considered as quasi-fixed factors in the short-run (we consider three-year variations).

When estimating this specification two main problems arise: 1) the endogeneity of regressors; 2) the direction of causality. The endogeneity problem may arise because of the correlation between some omitted factors which enter the error term and the proxies for technological capital included such as ICT or R&D capital[18]. If there are omitted factors affecting both R&D or ICT and the skill-ratio, then the estimates of γ are biased. The second problem is due to the fact that γ may simply reflect correlation rather than causation: is the stock of technology that affects the skill-ratio or viceversa?

The first problem can be mitigated by time differencing equation (1), in order to sweep out the firm specific fixed effects, obtaining the following specification:

$$\Delta SR_{it} = \eta + \alpha\Delta\ln(K_{it}) + \beta\Delta\ln(Y_{it}) + \gamma\Delta TECH_{it} + \delta\Delta\ln(W^S_{it} / W^U_{it}) + v_{it} \quad (2)$$

where $v_{it} = \varepsilon_{it} - \varepsilon_{it-3}$ and $\eta = 3k$. Here we consider long differences, precisely three-year differences. In analogy with Machin and van Reenen (1998), we use as a proxy for the change in the stock of technology the ratio of R&D and ICT expenditures on Y (in %). Time differencing equation (1) removes the persistent component in the error term (i.e. the firm specific fixed effect u_i), which may be correlated with persistent factors determining the stock of technology, such as R&D expenditures, and contributes to mitigating the endogeneity problem. However, for non-persistent expenditures such as ICT, probably some residual correlation may still remain. For this reason and to attenuate the second problem (the direction of causality) we use the lagged values of the proxies of $\Delta TECH_{it}$[19].

In this paper, we use the variation of the skill-ratio occurred between 1997 and 2000. This enables us to use the lagged intensities of R&D and ICT, i.e. those provided by the 1995-1997 wave, which can be considered as predetermined with respect to changes in the dependent variable, which refer to the 1997-2000 period. This also contributes to avoiding the problem of the "double counting" of R&D personnel[20].

[18] We focus on the technological variables only, but the problem may also concern other included regressors.

[19] Machin and van Reenen (1998) observe that if technology adoption only responds slowly to shocks to skills, because of high adjustment costs, the proxies for technology can be considered as predetermined variables. However, this is more likely to be true for R&D than for ICT expenditures.

[20] The problem arises when considering the variation in the SR and R&D expenditures in the same period. In that case a positive correlation between the SR and R&D expenditures may be simply spurious and driven by the fact that the amount of non-production workers also includes R&D employees (since most of the R&D expenditures relates to personnel costs).

Like many other authors[21], we decide to omit from the analysis the wage ratio. This is mainly done for two reasons. Firstly, wages are not provided by the survey and need to be imputed from other sources. However, matching different datasets usually requires some strong assumptions and a considerable level of discretionality on the part of the researcher that we prefer to avoid at this stage of the analysis. Secondly, the wage ratio is likely to be endogenous[22].

As we have anticipated, we shall consider two different proxies for skilled and unskilled workers. The first is the one most often used in the literature, where production workers (blue collars) are considered as the unskilled workers and the non-production workers (white collars) are considered as the skilled workers. The second uses, instead, the educational qualification of workers. In particular, on the grounds of the wide diffusion of secondary schooling in developed countries, we define as skilled workers those possessing a university degree and unskilled the ones possessing lower educational qualifications.

5. Empirical Results

As we said, we estimate the variation in the skill-ratio occurred between 1997 and 2000, which is our dependent variable, as a function of the variation in capital stock (in natural logarithms), the variation in turnover (in natural logarithms), and some proxies of firms' R&D and ICT intensities. Variations in log-capital and log-turnover refer to the 1997-2000 period while the proxies of change in technological capital are 3 year-lagged (i.e. are taken from the 1995-97 wave of the SIM). We consider as a proxy of firms' R&D and ICT intensities the amount of total 1995-1997 expenditures on total 1995-1997 turnover in %[23].

The first analysis uses as dependent variable the skill-ratio defined as the ratio between the number of non-production and production workers in a firm. During the period 1997-2000 there has been an average increase in the skill-ratio of 0.056 units. We estimate different specifications. A first specification (I) includes among the explanatory variables only measures of variations in log-capital, log-turnover and proxies of technological capital, whilst a second one (II) also includes various controls for geographic area (North-East, North-West, Centre, South and Islands), NACE two-digit industry codes, firm size in terms of workers (11-20, 21-50, 51-250, 251-500, >500, as grouped in the survey), dummies for break-ups and take-overs and a dummy for organizational innovations introduced in the period 1995-1997[24].

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[21] See for instance the articles reviewed in Machin (2001, p. 760).

[22] We do not think that omitting wages is a major flaw for our analysis. When we omit the wage ratio the estimated effects of firms' R&D and ICT are the 'overall' effects which act through the change in the relative prices of skilled and unskilled workers and through the degree of complementarity of technology with each type of workers. However, wage dynamics is likely to be determined by R&D and ICT more at the economy aggregate level than at firm level, and the second channel is likely to dominate (especially in Italy where unions and centralised wage setting are relatively strong compared to the US and the UK). At partial support of this speculation, from the analysis at industry level it emerges that estimates of the effect of R&D change only marginally when controlling for the wage ratio (see Machin and van Reenen, 1998, p.1243).

[23] Used for instance in Machin and van Reenen (1998).

[24] The coefficients on all control variables are not reported in the tables. The full set of results is available upon request from the authors.

From Table 5 it is immediate to note that neither R&D nor ICT are statistically significant in explaining the skill-ratio in specifications I and II.[25] These findings can be explained having in mind the loose informative power of the WC/BC indicator and the characteristics of Italian R&D activities (discussed in sections 1 and 2; see also below). In other words, an increase in the R&D or ICT intensities does not necessarily imply a generalised increase in the WC/BC ratio. A significant portion of Italian R&D activities has an incremental nature and is performed informally along the shop floor also by (internally trained) BC workers, while some R&D projects may make redundant some types of WC (reducing some routinary clerical jobs). Finally, the coefficient on the log-capital stock is not statistically significant[26] while that on log-turnover is negative and statistically significant at the 1% level. This latter result is not peculiar of our analysis but has been observed in other studies (see for instance Machin and van Reenen, 1998) and suggests that in the short-run an increase in production requires a relative increase in the stock of production workers.

TABLE 5. REGRESSIONS WITH R&D AND ICT, WITH AND WITHOUT CONTROL VARIABLES

	Specification I		Specification II	
Variables	**Coef.**	**s.e.**[a]	**Coef.**	**s.e.**[a]
DlnK	0.017	0.055	0.015	0.059
DlnY	-0.304**	0.121	-0.277**	0.129
R&D/Y	0.017	0.029	0.022	0.030
ICT/Y	0.058	0.044	0.057	0.043
Organizational innovations	-	-	-0.010	0.055
N. observations	1,037		1,037	
R^2	0.021		0.041	
Homoskedasticity[b]	128.79 (0.00)		9.07 (0.00)	

Note: *** Significant at 5%. [a] Standard errors are obtained using the Huber-White robust estimates whenever the hypothesis of homoskedasticity is rejected. Huber-White estimates of the standard errors are also more robust to non-normality; [b]Breusch and Pagan (1979) test for the presence of multiplicative heteroskedasticity. The null hypothesis is absence of homoskedasticity. The test is distributed as a Chi²(1), p-value in brackets.*

The dependent variable is the 1997-2000 change in the ratio between white collars and blue collars. Specification II also includes controls for geographic location, NACE two digit sectors, firm size and dummies for break-ups and take-overs.

[25] The estimation sample does not include all firms in the panel (1,297, see section 3) since observations with missing values in the dependent or independent variables are dropped from the analysis.

[26] The capital stock is derived from balance sheet data and is evaluated at the net 'historical cost' that is cost originally borne by a firm to buy the good reduced by the depreciation measured according to the fiscal law (*Fondo di ammortamento*), which accounts for obsolescence and use of the good. We estimated the models in Table 5 also using the natural logarithms of the real value (in millions of 1995 Italian lira) of the investment flows in the period 1995-1997 and the results were not different.

TABLE 6. REGRESSIONS WITH R&D INTERACTED WITH PAVITT SECTOR AND ICT, WITH CONTROL VARIABLES

	Specification III	
Variables	**Coef.**	**s.e.**[a]
DlnK	0.020	0.059
DlnY	-0.269**	0.127
R&D/Y Supplier Dominated	0.110	0.071
R&D/Y Scale Intensive	-0.178	0.138
R&D/Y Specialised Supplier	-0.003	0.016
R&D/Y Science Based	0.076	0.087
ICT/Y	0.058	0.041
Organizational innovations	-0.016	0.042
N. observations	1,037	
R^2	0.063	
Homoskedasticity[b]	52.94 (0.00)	

Note: *** Significant at 5%. [a] Standard errors are obtained using the Huber-White robust estimates whenever the hypothesis of homoskedasticity is rejected. Huber-White estimates of the standard errors are also more robust to non-normality; [b]Breusch and Pagan (1979) test for the presence of multiplicative heteroskedasticity. The null hypothesis is absence of homoskedasticity. The test is distributed as a Chi²(1), p-value in brackets.*
The dependent variable is the 1997-2000 change in the ratio between white collars and blue collars. Specification III also includes controls for geographic location, NACE two digit sectors, firm size and dummies for break-ups and take-overs.

TABLE 7. REGRESSIONS WITH R&D AND ICT BY DESTINATION, WITH CONTROL VARIABLES

	Specification IV	
Variables	**Coef.**	**s.e.**[a]
DlnK	0.013	0.060
DlnY	-0.287**	0.132
R&D/Y Improvement old processes	-0.235*	0.122
R&D/Y Improvement old products	-0.051	0.036
R&D/Y Introduction new processes	0.217**	0.094
R&D/Y Introduction new products	0.034	0.039
R&D/Y Other purposes	0.047**	0.019
ICT/Y Hardware	0.045	0.062
ICT/Y Software	0.101	0.088
ICT/Y Telecommunications	0.537	0.751
Organizational innovations	0.000	0.041
N. observations	1,027	
R^2	0.069	
Homoskedasticity[b]	5.31 (0.02)	

Note: *** Significant at 5%, * significant at 10%. [a] Standard errors are obtained using the Huber-White robust estimates whenever the hypothesis of homoskedasticity is rejected. Huber-White estimates of the standard errors are also more robust to non-normality; [b]Breusch and Pagan (1979) test for the presence of multiplicative heteroskedasticity. The null hypothesis is absence of homoskedasticity. The test is distributed as a Chi²(1), p-value in brackets. The dependent variable is the 1997-2000 change in the ratio between white collars and blue collars. Specification IV also includes controls for geographic location, NACE two digit sectors, firm size and dummies for break-ups and take-overs.*

In order to investigate the existence of a different impact of R&D on skills according to firms' different technological opportunities, we interacted R&D intensity with Pavitt sector dummies in specification III, which also includes all the control variables included in specification II. However, also in this case none of the interaction terms turn out to be statistically significant (see Table 6). This result reinforces our previous guess that, given the informative limits of the BC/WC ratio, an unambiguous effect on workers' skills cannot be identified; consequently, not even the disaggregation of the R&D effort by performing sectors can capture the possibly differentiated effect of technology across skills and firm's functions.

Using the same skill ratio, a different heuristics strategy is to improve the informative power of the technological variables. In principle, ICT and R&D could be a complement or a substitute for "skilled" labour, depending on what purpose the new technologies are used for. R&D, for instance, can be undertaken to make marginal improvements to old products or old processes which may not be technologically advanced and may not require more skilled labour; alternatively, R&D activities could be targeted at introducing new processes or products, which may be unskilled labour-saving and have a higher technological content, respectively. Likewise, ICT *per se* could be skilled labour-saving, in terms of non-production workers, if it mainly involves automatisation of simple clerical tasks (see Bresnahan et al., 2002).

For these reasons distinguishing the R&D and ICT intensities by destination may give new useful insights into the main sources of the skill bias. We divide R&D intensity in expenditures devoted to improvement of old products, improvement of old processes, introduction of new products, introduction of new processes and for other purposes. ICT intensity is distinguished into expenditures on hardware, on software and on telecommunications. The results of this specification (IV) are shown in Table 7. Also in this case we add the full set of controls of specification II. Our results do not show any effect of ICT on the skill-ratio. By contrast, a significant effect for R&D now emerges. R&D devoted to the improvement of old processes is associated with a reduction in the skill-ratio, which is only marginally not significant at the 5% level (in particular a one per cent point increase in R&D/Y devoted to this purpose is associated with a 0.23 units reduction in the skill-ratio). The effect of R&D devoted to the introduction of new processes on the skill-ratio is positive (0.22) and statistically significant at the 5% level. Also R&D devoted to other purposes turns out to be positively related to the skill-ratio. So, once disaggregated into its components, R&D exerts two distinct (counterbalancing) effects on the skill ratio, according to the degree of innovativeness of the activities involved (old versus new).

As also discussed in section 2, the type of indicator we are using for the skill-ratio, the ratio between white collars and blue collars - although is widely used in the economic literature - is not necessarily a good proxy for the skills endowment of a firm, and hence for SBTC. Indeed, technological change may not necessarily determine a reallocation of workers between non-production and production tasks, while it may cause a general skill upgrading within a firm. For example, both former production and non-production tasks may become more complex and require a more skilled labour force. Moreover, occupation-based indicators are more sectorally-biased than those based on educational attainment (see also Chun, 2003). For these reasons, we consider a more refined indicator of skill-ratio, taking the ratio between workers with a university degree and those with lower educational qualifications. During the period under study (1998-2000) this second indicator of skill-ratio has registered a fall of 0.009 units[27].

We have estimated the equivalents of specifications I, II, III and IV. In specification I in Table 8 the coefficient on R&D intensity is positive and significant at the 5% level. A one per cent point increase in R&D intensity is associated with a 0.0083 units increase

[27] In particular, on average both the stock of graduate and non-graduate workers increased but the increase of the latter was faster causing a decline in the skill-ratio.

in the skill-ratio. This estimate is robust to the inclusion of control variables (see specification II in Table 8). Moreover, it is interesting to note the positive and significant effect of the dummy for organizational innovations introduced in 1995-1997. Further, our estimates in specification III in Table 9, which include interactions between R&D intensity and Pavitt sectors, show that most of the significant positive effect of R&D on the skill-ratio can be attributed to firms in Supplier Dominated and Science Based sectors. In particular, while the first interaction term (between R&D and the Supplier Dominated category) is positive and of the same order of magnitude as the general effect estimated in specification II (precisely, its coefficient is equal to 0.0087) - although not statistically significant at conventional levels - the effect of the second interaction term (between R&D and the Science Based category) is bigger (0.036) and significant at the 1% level.

TABLE 8. REGRESSIONS WITH R&D AND ICT, WITH AND WITHOUT CONTROL VARIABLES

	Specification I		Specification II	
Variables	**Coef.**	**s.e.**[a]	**Coef.**	**s.e.**[a]
DlnK	-0.007	0.005	-0.014**	0.007
DlnY	-0.077*	0.046	-0.082*	0.049
R&D/Y	0.009**	0.004	0.008**	0.004
ICT/Y	0.005	0.015	-0.002	0.015
Organizational innovations	-	-	0.016*	0.008
N. observations	825		825	
R^2	0.018		0.056	
Homoskedasticity[b]	1348.82 (0.00)		4819.95 (0.00)	

Note: *** Significant at 5%, * significant at 10%. [a] Standard errors are obtained using the Huber-White robust estimates whenever the hypothesis of homoskedasticity is rejected. Huber-White estimates of the standard errors are also more robust to non-normality; [b]Breusch and Pagan (1979) test for the presence of multiplicative heteroskedasticity. The null hypothesis is absence of homoskedasticity. The test is distributed as a Chi²(1), p-value in brackets. The dependent variable is the 1997-2000 change in the ratio between graduate and non-graduate workers. Specification II also includes controls for geographic location, NACE two digit sectors, firm size and dummies for break-ups and take-overs.*

Table 9. Regressions with R&D interacted with Pavitt sector and ICT, with control variables

	Specification III	
Variables	**Coef.**	**s.e.**[a]
DlnK	-0.014*	0.007
DlnY	-0.080	0.049
R&D/Y Supplier Dominated	0.009	0.006
R&D/Y Scale Intensive	-0.002	0.009
R&D/Y Specialised Supplier	0.005	0.005
R&D/Y Science Based	0.036***	0.013
ICT/Y	-0.002	0.015
Organizational innovations	0.016*	0.008
N. observations	825	
R^2	0.070	
Homoskedasticity[b]	4506.73 (0.00)	

Note: **** Significant at 1%, * significant at 10%. [a] Standard errors are obtained using the Huber-White robust estimates whenever the hypothesis of homoskedasticity is rejected. Huber-White estimates of the standard errors are also more robust to non-normality; [b]Breusch and Pagan (1979) test for the presence of multiplicative heteroskedasticity. The null hypothesis is absence of homoskedasticity. The test is distributed as a Chi^2(1), p-value in brackets. The dependent variable is the 1997-2000 change in the ratio between graduate and non-graduate workers. Specification III also includes controls for geographic location, NACE two digit sectors, firm size and dummies for break-ups and take-overs.*

TABLE 10. REGRESSIONS WITH R&D AND ICT BY DESTINATION, WITH CONTROL VARIABLES

	Specification IV	
Variables	**Coef.**	**s.e.**[a]
DlnK	-0.014*	0.007
DlnY	-0.083*	0.051
R&D/Y Improvement old processes	0.020**	0.009
R&D/Y Improvement old products	0.012	0.008
R&D/Y Introduction new processes	0.007	0.005
R&D/Y Introduction new products	0.001	0.014
R&D/Y Other purposes	0.029	0.058
ICT/Y Hardware	-0.026	0.037
ICT/Y Software	0.024	0.028
ICT/Y Telecommunications	-0.029	0.099
Organizational innovations	0.015*	0.008
N. observations	817	
R^2	0.058	
Homoskedasticity[b]	4786.99 (0.00)	

Note: *** Significant at 5%, * significant at 10%. [a] Standard errors are obtained using the Huber-White robust estimates whenever the hypothesis of homoskedasticity is rejected. Huber-White estimates of the standard errors are also more robust to non-normality; [b]Breusch and Pagan (1979) test for the presence of multiplicative heteroskedasticity, distributed as a $Chi^2(1)$, p-value in brackets.*
The dependent variable is the 1997-2000 change in the ratio between graduate and non-graduate workers. Specification IV also includes controls for geographic location, NACE two digit sectors, firm size and dummies for break-ups and take-overs.

As it stands, these results are not surprising for those who know the characteristics of the R&D activities performed in Italy. As we noted in section 2, the Italian model of specialization rests on traditional sectors (mainly Supplier Dominated sectors). These traditional sectors are marked by an internal polarization: they contain a large share of small and medium firms, which do not rely on R&D as the main source of technological change, and a smaller subset of firms which do perform relevant R&D activities. Consequently, in the aggregate, in these sectors a generalised effect of R&D on upskilling is not likely to emerge, while this effect may take place within a small subset of leading firms. Differently, in Science based sectors, there is a higher degree of technological opportunities and a structurally larger investment in human capital: here a sustained level of R&D activities and an upskilling trend are a necessary condition for every firm to remain competitive in the market.

Finally, in specification IV (Table 10), where R&D and ICT are distinguished by destination, the sole statistically significant effect emerging is that of R&D devoted to improvement of old processes, whose effect is positive and significant at the 5% level. In particular, a one per cent point increase in the intensity of R&D devoted to improvement of old processes is associated with a 0.020 increase in the ratio between workers with a university degree and those with lower educational qualifications. Again, these results are coherent with the findings of the literature on innovative activities in Italian firms: these activities are mainly incremental and even the most technologically intensive sectors (as the Science Based and Specialised Supplier ones) do not distinguish themselves for a particularly higher R&D intensity, as they should (see also section 2, in particular Table 1).

Concerning ICT, we do not generally find any significant effect on the skill-ratio; moreover, this happens with both definitions of skills. Several explanations are possible. First, unlike R&D expenditures, which are borne to obtain specific technological advantages and that signal an uncontroversial 'above-average' endowment of human capital within the performing firm, ICT outlays concern general-purpose and pervasive technologies, suitable to carry out different tasks. So, in principle ICT-based indicators are less suitable to discriminate between high and low technology firms, and between high and low skilled workers, than R&D-based indicators. Moreover, in the case of ICT the choice of the 'right' skill indicator seems to be more crucial: in fact, ICT could have opposite effects on different categories of tasks, within the same type of job (WC/BC) or educational class (tertiary or secondary degree)[28]. However, a further refinement of the analysis is not possible in our case, since we do not have information on the actual tasks/functions performed by workers.

Finally, and perhaps most importantly, the ICT impact on the skill composition of the workforce may be quantitatively very limited and severely delayed. As discussed in the "delay hypothesis" (David, 1990), the productivity and employment effects of several important technologies materialize with a delay, well after their introduction phase. Since during the Nineties Italy suffered a relevant gap in the ICT diffusion with respect to the other comparable European countries (see section 2 - particularly Table 3), the delay hypothesis could also explain the lack of a significant impact of ICT on the upskilling trend of the labour force found in our study.

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[28] For a recent contribution distinguishing the impact of technology across tasks and firms' functions, see Maurin and Thesmar (2004).

CONCLUSION

In this paper we perform an empirical analysis of the effect of some proxies for firms' technological capital, such as R&D and ICT expenditures on turnover, on the skill-ratio using Italian manufacturing data. As an indicator of the skill-ratio we have considered either the ratio between non-production (or white collars, WC) and production workers (blue collars, BC), or the ratio between university graduate (G) and non-graduate workers (NG).

From the analysis using the first indicator of skill-ratio (WC/BC) we do not generally observe a positive effect of R&D. However, when we consider R&D expenditures by destination we find a negative effect on the skill-ratio of R&D devoted to improving old processes and a positive effect of R&D expenditures borne to introduce new processes. This suggests that the effect of R&D on the skill-ratio might not be homogeneous across destinations; particularly, since new processes imply a higher skill content and a stronger unskilled labour saving potential (while the reverse should happen with old processes), this evidence is meaningful and in line with the SBTC hypothesis.

However, the support for SBTC is stronger and more convincing when we consider the alternative indicator for the skill-ratio (G/NG), which is a better proxy of the actual skill endowment of workers. In fact, here we find an overall positive effect of R&D on skills, even without further disaggregations. Moreover, by interacting R&D with Pavitt sectors we note that most of the positive correlation between the R&D intensity and the skill-ratio is attributable to the Supplier Dominated and Science Based sectors. Although with different characteristics, a positive relation between human capital and technological level in these two Pavitt sectors signals a genuine SBTC phenomenon.

Finally, our analysis of the effect of the R&D intensity disaggregated by destinations shows that only the effect of R&D devoted to improving old processes is positive and significant at the 5% statistical level, while the effect of the other categories of R&D is positive but never significant at conventional levels. We believe that these original results on SBTC in Italy can be coherently related to the findings uncovered by the literature on the innovative activities of Italian firms.

As far as ICT is concerned, we do not generally find significant effects, either positive or negative, on the skill-ratio. This finding is common to both definitions of the skill-ratio. On the light of the Italian gap on ICT diffusion, still relevant during the mid-Nineties, this evidence could merely reflect a delay in the adjustment path, likely to disappear as more investment in ICT and time are allowed for. Furthermore, the fact that when considering the skill-ratio defined in terms of educational qualifications the effect of organizational innovations is positive and significant, and that the latter are often coupled with ICT expenditures, seem to suggest that, as far as the latter are concerned, the indirect effect in terms of skill-biased-organizational-change may be stronger than the direct effect in terms of SBTC, an hypothesis that suggests possible lines of future research.

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