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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 literature finding support for 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. This is interesting since, as well known, Italy is a 'late comer' country and stands as a follower in the realm of new technologies. We estimate employment-share equations and find evidence that the impact of R&D on the skill-ratio (the ratio between white collars and blue collars) varies across Pavitt sectors and according to destination of R&D. However, whenever evidence supporting SBTC (i.e. a positive impact on the skill-ratio) is found, it mainly operates through the reduction of unskilled workers. This can be easily reconciled with the structural features of Italian manufacturing where traditional sectors and small and medium sized firms prevail, innovative activity is scarce and mainly labour-saving and the capacity to absorb skilled labour rather limited.

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1 Introduction

Technological change - particularly Information and Communication Technologies (ICT, henceforth) - is thought to mark a fundamental modification in the composition of economic activity and in the way it is organized. Moreover, new technologies seem to progressively shift the composition of national GDPs towards more "knowledge intensive" products and services (e.g., European Commission, 1994, OECD 1996). Consequently, the digital and technological breakthroughs are expected to exert an impact on the input-mix that firms use. In particular, technology could structurally change the demand for labour, requiring new skills and changing the organization of production.

Since the early Nineties, several contributions have investigated the consequences of the diffusion of new technologies on the composition of the labour force, focusing on a possible bias towards more skilled labour induced by technological capital. In other words, new technologies would increase the need for workers possessing new knowledge and abilities producing 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 an 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).

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, especially Italy on which we shall focus our analysis, since they often display different labour market conditions

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and stand as followers in the realm of new technologies.[1]

The structure of the paper is as follows. In section 2 we present a brief discussion of the relevant literature, together with an analysis of the main methodological problems still at the core of the SBTC debate. In section 3 we highlight some structural characteristics of the Italian economy, focusing on the skill composition of the workforce and the scientific and technological level of the country. In section 4, 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 5 discusses our empirical specification, together with the main econometric issues. Section 6 presents the main results. Section 7 concludes.

2 Literature review

2.1 The debate on the 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. Despite unavoidable differences across countries and time periods, the empirical evidence now available outlines some clear 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 dynamic in terms of number of workers, but also reflected a faster price dynamic: in other words, the unit wage of skilled labour, relatively to the unskilled, has risen (see Acemoglu, 2002). At least, this is true for the US since the early Eighties, while for other countries the same tendencies have appeared later. Also, a possibly related phenomenon is that several countries - especially the Anglo-saxon ones (mainly the US and the UK) - have experienced a marked polarization of the earnings structure (higher wage inequality). Finally, if the level of education and the non-production labour share can be taken as satisfactory proxies of the skill level of the workforce, one must also observe that the supply of skilled labour has 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.

[1] In particular, Italy still lags behind similar European countries with respect to both production and adoption of ICT - see section 3.

However, at this point one should also explain the determinants of this purported demand shift. Several explanations have been proposed in the literature, linking labour market changes to phenomena such as technological shocks, economic downturns, trade flow changes, institutional rigidities and others. 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. 1) The trade-based explanation focuses on the dynamic of globalization affecting national economies, which open themselves to foreign competition and, as a result, undergo a change in their specialization and foreign trade structure. 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. Consequently, the rise and development of modern industries would lead to higher demand for skilled workers, and the wage bill at the aggregate would shift towards higher wages and salaries. Contributions stressing the trade-based explanation include Lawrence and Slaughter (1993), Wood (1994), Borjas and Ramsey (1995) and Haskel and Slaughter (2001), among the others. 2) The technology-based approach (or SBTC), clearly identifiable since the seminal contributions of Bound and Johnson (1992) and Berman et al. (1994), focuses on the impact exerted by scientific activity, knowledge generation and technology diffusion; it has attracted a larger consensus and has eventually affirmed as the main basic explanation for the up-skilling trend.[2] Although the SBTC contributions do not ignore the possible influence exerted by other explanatory factors (for instance, trade flow changes),[3] they mainly focus on the relation of complementarity existing between capital, new technology and skilled labour. The complementarity concept, which was originally proposed by Nelson and Phelps (1966) and Griliches (1969), can be thought as a feature related to the classical labour-capital substitution debate, and argues that not only the production but also the effective adoption of new technologies requires new knowledge and abilities available in the labour force. So, the complementarity relation implies that a new (more-skilled) kind of labour is needed to produce and operate the new technologically advanced (and knowledge-intensive) capital. However, since workers' education and training activities are costly and lengthy processes, the resulting skill-mismatch might also imply the 'obsolescence' of the abilities embodied in the less and/or old skilled portion of the workforce, and its definitive dismissal, due to the fact that retraining is too difficult. Summarizing, as demonstrated by the "compensation" literature (for a recent reappraisal, see Vivarelli 1995 and Vivarelli and

[2]The literature on the SBTC has become quite extensive. The interested reader can find some updated reviews in Acemoglu (2002) and Card and DiNardo (2002).

[3]For example, the seminal contribution of Berman et al. (1994) argues with a "shift and share" analysis that in the US for the period 1959-1987 the variation of the non-production labour share is mainly accounted for by technological variables, and only negligibly by trade or defense public procurement.

Pianta, 2000), capital and technology can be labour-saving, and inevitably less skilled labour is more likely to be reduced, at least at the firm-level. Finally, some contributions (see Bresnahan et al., 2002) show that the effective deployment of new technologies (ICT-based) brings complementary organizational transformations, implying a change in the way tasks are performed: the latter, in turn, require new skills in the workforce. As a consequence, the potential of new technologies is fully reaped only within a virtuous cycle among technology adoption, organizational change and skills availability. Following this line of reasoning, from the complementarity between new technological capital and skilled labour one can draw the conclusion that employers should be ready to reward (a larger number of) skilled employees for the higher productivity allowed by technological change. According to the different contexts, the up-skilling trend of the skilled work wage bill share could reflect only a quantity phenomenon or also a price effect. In any case, it is undeniable that the implementation of more productive technologies and organizations requires new complementary skills in the workforce. However, there are other articles in which organizational change in itself seems to play the role of the main explanatory variable in the regression analysis, independently from 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 1992-1996) and British firms (in 1984-90). Moreover, the preexisting skill endowment affects in turn the rate of organizational change: analyzing the determinants of the latter (as in the form of delayering of hierarchies), the authors find that shortage of skilled workers (as proxied by educational wage differentials) reduces the probability of introducing changes in organization. Similarly, for a panel of Italian firms monitored during the period 1991-97, Piva and Vivarelli (2002a,b) uncover a significant and positive relation between a dummy for organizational change and the existence of skill bias. In particular, using the SUR estimation method, Piva and Vivarelli (2002a) assess separately the influence of regressors on "white collar" and "blue collar" (respectively WC and BC, henceforth) workers and find that the impact of the "organizational change" regressor is significant (and negative) only for the BC ones (we shall go back to the point in more details in the next section).

However, at a closer look the "trade" and the "technology-based" explanations (the latter including organizational change), rather than being alternative, are complementary and even rooted - at least partially - in the same microeconomic phenomenon: a change in the production function and its input-mix at the firm-level. In fact, changes in the trade specialization of a country inevitably reflect those changes happening at the micro-level, where new processes and products are introduced, organizations and routines are modified and new kinds of skills are demanded.[4]

In short, a sound analysis of the SBTC hypothesis should be carefully micro-founded at the firm-level, in order to avoid some ambiguities often present in the SBTC literature. This does not imply that the firm-level analysis is the only "necessary and sufficient" test for SBTC to be carried out, on the grounds that the firm is the place where the input-mix substitution is taking place. As an example, it would miss the substitution dynamic between imports and domestic production, which by definition can only be assessed at the sectoral or even a more aggregate level.[5] A satisfactory methodology should consist instead of (at least) a double-layer analysis, coupling the micro-level test with the analysis at a more aggregate level. However, up to now most of the empirical literature is built on sectoral datasets, due to both lack of firm-level data and problems of samples representativeness. Now, the sectoral aggregation yields only a synthesis of all the tendencies, displaying the net effects of different (and possibly counteracting) forces, including the SBTC component. To cite just the major problems, if we decompose the aggregate variation of the skilled share of the workforce into the "between sectors" and "within sectors" shares (as in Berman et al., 1994), we are left with the problem of having in the "within" portion the net effect of different dynamics, which individually remain uncovered: the firms' demography dynamics (birth, growth and exit of firms, yielding typically a composition effect), the national delocalization of production and the changes in the degree of vertical integration of an industry.[6] As a matter of fact, if the analysis is carried out at the sectoral level, these phenomena remain largely undisclosed and their impact on the skill trend is not separately ascertained; instead, at the firm-level, it is easier to capture firms' heterogeneous behaviour and its exogenous determinants.[7] It follows that at the sectoral level the observed skill-upgrading dynamic has a mixed causation, being jointly explained by technical change and the other structural factors outlined above.

To summarize, a sound micro-level test of SBTC is called for, and this test is particularly relevant for those countries which are technological followers

[4]Among the works which have already attempted to give a joint assessment of the two explanatory factors, an interesting contribution is that of Morrison Paul and Siegel (2001), who also explore 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 substantial and robust than those directly played by trade and outsourcing.

[5]For an assessment of the foreign and domestic demand roles in explaining the upskilling trend in France, see Goux and Maurin (2000).

[6]Obviously, while the second phenomenon has a 'horizontal' character, the third is by definition 'vertical' and reflects phenomena such as the increasing tertiarization of production and firms' outsourcing choices.

[7]For example, the most important industrial dynamics phenomena are invisible at the sectoral level, where their influence is mixed with SBTC, while most of them can be analyzed at the firm-level.

with respect to the US, and might display specific features and characteristics that are likely to differently shape the relation between technological change and skill upgrading. Having this in mind, we now move to discuss some recent contributions focusing on the EU and Italian cases.

2.2 The European experience and the Italian case

European countries have joined the "digital bandwagon" with substantial delays with respect to the US and an EU gap is still present, as figures on ICT penetration clearly show. In 2001, IT spending over GDP is 3.45% for the EU and 5.45% for the US and IT per capita spending is respectively 745 and 1,522 euros. Moreover, the US nowadays enjoys a more pervasive diffusion of IT than the EU, both in business and household usage: for example, the number of business PCs per 100 WC workers is respectively 138 and 77, while the gap widens in the number of PCs per 100 units of population (cf. EITO, 2003, p. 76). Consequently, the US and EU experiences with regard to skill bias may be different and the European delay in R&D activities and ICT adoption could indeed explain some features of the EU employment patterns. 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 techno-economic and socio-institutional adjustment(for e.g., Freeman 1987, David, 1990, 2000, Petit and Soete, 2001). In particular, when a new technological paradigm affirms, it is only after an initial "slowdown" phase - in which productivity, employment and even output plummet - that the economy recovers and economic indicators return to be positive, with a corresponding surge in productivity and net creation of employment. In fact, technological activities are inherently affected by discontinuities and "learning by doing" phenomena, for a series of reasons. First, R&D activities are risky, expensive and are usually performed by medium and big enterprises, while small firms are indirectly affected by sectoral spillovers with substantial time lags. Second, ICT are potentially pervasive technologies (see Helpman, 1998), but they still present scale and knowledge barriers, so that their diffusion and virtuous implementation require a coherent and systemic adjustment of the entire economy. Coherently with this view, in a given country also the up-skilling trend of employment could be retarded or even impeded if the process of technological upgrading is delayed or unbalanced across sectors. Having this perspective in mind, the puzzling evidence on SBTC available for most European countries can be more easily understood. At the sectoral level, the main hypothesis of SBTC is firmly 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) during the period 1973-89, and find evidence of a significant and positive association between R&D intensity and the up-skilling trend: moreover, the sectors with higher R&D intensity exhibit in all countries faster skill-upgrading. In this study, which is based on a disaggregation of the manufacturing industry in 15 sectors, the skill bias is measured as an increase in the wage-bill share of non-production workers. According to the authors, the relation found between R&D and the up-skilling trend, being evident for all the 7 countries, should be interpreted as having a technological nature: a series of facts supports this conclusion. First of all, the relation is proved robust both to endogeneity tests and to alternative specifications, including other technology variables such as ICT investment intensity. Further, also the inclusion of trade-related measures does not alter the significance of the technology variables.[8] In other works focused on individual European countries the evidence in favour of SBTC is less straightforward instead. For the UK, the results are generally similar to those found for the US: for example, in Machin (1996) the SBTC hypothesis is confirmed both at the sectoral and the firm-level. At the sectoral level, using 3-digit data in long differences over the period 1979-90, a positive relation between R&D intensity, number of innovations produced and used and skilled labour emerges; furthermore, with micro-data, in a sample of 402 firms covering the period 1984-1990, the authors uncover a significant positive relation between the use of computers and skilled labour. However, at least at the firm-level, the association between computer usage and skilled labour is somehow tautological and a more complete test of SBTC should also control for the dynamics of the unskilled. Differently from the UK, the evidence for the other European countries is less unequivocal. Goux and Maurin (2000) study the determinants of labour demand using sectoral surveys of the French labour force, covering the period 1970-1993 and providing wage and workers' educational levels by industry.[9] Moreover, these demand-side data are complemented with supply-side datasets providing information on the diffusion of computers and other micro-electronic technologies by industry and occupational category. Undoubtedly, these technologies are a vector of technological progress - and consequently, by their asymmetric impact on workers with different skill levels, they imply a shift in the sectoral labour demand. However, in the French case their overall role on the generation of skill bias appears to be modest: in the period 1970-93 the diffusion of computers and that of new (automation) technologies explain respectively only a fall of 2.1 and 1 per cent points in the unskilled workers' share of total employment. Instead, according to Goux and Maurin (2000, p. 606), the almost entire up-skilling trend is accounted for by the "between" dynamics (almost 2/3 of

[8]In a related work, carried out with a "shift and share" analysis for a larger set of countries, Berman et al. (1998, p. 1257) verify that the aggregate up-skilling 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 up-skilling trend explained by variations in trade flows and domestic demand, is well inferior.

[9]The French economy is both studied in a 34-sector disaggregation and in its manufacturing sub-section, and the results are substantially similar, with respect to the portion of the skill bias explained by technology variables.

the reduction of the unskilled share of employment) - mainly due to changes in the domestic demand for goods and services - while the remaining (1/3) is attributable to a "within" component, which is not technology but the relative fall in the labour cost of the skilled (workers with a "baccalauréat" degree or more). To summarize, according to the authors, the French economy has witnessed a process of skill upgrading mainly driven by a change of specialization, with a reduction of the weight of the traditional sectors and an increase of those more knowledge-intensive. This structural change, which naturally raised employment opportunities for the skilled, was also reinforced by a "within" process of up-skilling of the workforce, backed by the institutional setting of the French economy (minimum wage legislation, compulsory training, etc.) and fostered by the favorable wage dynamics.

For the France case, again, Mairesse et al. (2001), perform a firm-level analysis looking at the correlations between indicators of technology, productivity and skills. They use data from (four) samples of manufacturing and services firms over two five-years periods: 1986-90 and 1990-94. IT intensity is proxied by three different indicators: the share of "computer equipment" in the firm total capital and the shares of "computer" and "electronics" specialists on total employment. Moreover, two additional indicators for R&D intensity are used: the share of formal R&D staff and that performing more "informal R&D and analytical activities", always on total employment. Correlations are explored both in the cross-sectional dimension of the data and in the time-series, in order to respectively assess the "between firms" differences and the "within firm" changes. As a main evidence, results in the cross-section are stronger in magnitude and significance. However, concerning the time-series specification, while IT and R&D indicators do not seem related to productivity and wage dynamics, they are significantly and negatively correlated with the share of BC workers. Moreover this evidence is clearly robust only in manufacturing, while in services there is a lighter negative correlation between IT labour and the share of WC and BC on total employment. The authors suggest that this evidence may support the SBTC hypothesis, although proper structural specifications would be needed.[10]

Concerning Italy, the empirical literature is very limited, the main reason being lack of suitable data. Official supply-side statistics (like the Labour Force Survey - *Indagine Trimestrale sulla Forza Lavoro*) provide a disaggregation of employment by skill levels, but lack a disaggregated sectoral dimension. On the demand side, instead, data on employment and labour costs, although fairly disaggregated by macro-industry (like those of National Accounts - *Contabilità Nazionale*), lack the skill dimension. So, for Italy a detailed sectoral test of the skill bias cannot be performed with the data provided by official statistics. The situation changes partially with reference to the analysis at the firm level. To our knowledge, the first contribution

[10]In fact, the authors emphasize that their specifications are not aiming at testing the causal nature of the relations.

focused on the Italian case has been that of Casavola et al. (1996). These authors created a panel of 35,174 firms representing the non-agricultural private sector for the period 1986-1990 matching two different datasets. The first is the INPS (*Istituto Nazionale della Previdenza Sociale*) firm-level dataset, which contains data on employment (separately for WC and BC workers, together with their average earnings) and distinguishes the units of observation by sector of activity, age and location of firms; the second gathers information on the company's balance sheet data, the CADS (*Company Accounts Data Service*), developed by the banking sector. The resulting panel enables the authors to assess both the wage and the employment dynamics, and to relate it to technological change, which is measured with a direct and comprehensive measure of firm's "intangible assets", constructed as the ratio of intangible capital (software, patents, R&D expenditures and other intangible assets) on total capital (equipment and plant). Despite the probably too large definition used for the technological variable,[11] the results seem to confirm the specificity of the Italian case, with respect to the SBTC phenomenon. On one side, in fact, the up-skilling trend is present: the WC employment share increases over the period, passing from 39.84% to 42.24% of the total wage bill (cf. p. 394). On the other side, the overall variance of earnings is mainly explained by a within phenomenon, and only residually by a between (WC and BC groups) effect (less than 30%). Moreover, Italy presents an asymmetric pattern between the two groups. Indeed, the shift and share analysis highlights that the "within" effect is systematically larger for the WC group: in other words, the earnings dispersion of the Italian workforce is mainly explained by the variability of wages within the group of WC workers. Moreover, 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, conducted both in a cross-section and in a panel setting, with "intangible capital", industry and location dummies and size (number of workers) as explanatory variables. In the cross-section, it emerges that there is a positive impact of technology on the wage bill share of the skilled and that this is mainly driven by changes in employment shares, which supports the "wage inflexibility" argument and the "demand shift" adjustment for Italy. The panel specification confirms that WC workers are increasingly demanded in conjunction with a higher technological profile assumed by firms; moreover,

[11] Indeed, our impression is that the inclusion of the other not-strictly technological items (business goodwill from mergers, other financial assets, etc.) might bias the regression results, accruing to the support of the SBTC hypothesis. This impression is reinforced by the consideration of the authors (see their Appendix, p. 408) that in a restricted sample of firms for which it is possible to reconstruct a truly technological "intangible capital", the cross-section results confirm that a larger definition of innovation, which also includes non-technological items, has a strong impact on the coefficient estimates. Moreover, when considering the sub-sample and panel estimates Casavola et al. (1996) do not find a statistically significant effect of the technological variables.

also in the panel, the evidence of a wage premium connected to the use of new technology (both for the WC and the BC and for the former with respect to the latter) is rather limited. The authors suggest a few explanations for the limited magnitude of the wage premium: a contemporary increase in the supply of skilled labour, the traditional inflexibility of the Italian centralized wage setting systems, and other institutional factors. Another series of contributions has been based on the Capitalia (formerly Mediocredito Centrale) dataset, covering and representative of manufacturing, used by Piva and Vivarelli (2002a,b). Their analysis focuses on a panel of 488 firms responding to the 3 three-year waves of the Capitalia Survey (1989-91, 1992-94, 1995-97) and estimates a labour demand equation derived from that used by Berman et al. (1994) and Machin and Van Reenen (1998), where labour costs are the only variable costs of production, while capital and technology are assumed to be quasi-fixed factors. In particular, Piva and Vivarelli (2002b) use a long difference specification where the variation (over 1991-97) of the dependent variable - the ratio of WC on BC workers - is regressed on output (sales), net capital and WC wages (all in differences over 1991-97), and on a series of lagged dummies for technology (R&D activities), organizational change and globalization,[12] referred to the period 1989-91.[13] The estimates show that the presence of organizational change is the only explanatory variable with a significant effect robust to alternative specifications. In particular, is the dummy for organizational change occurring at the production level (shop-floor) which is positively related to the skill-ratio. In a closely related paper build on the same dataset with a similar methodology, Piva and Vivarelli (2002a) use a Seemingly Unrelated Regression method, which presents the advantage of assessing the potentially different dynamics affecting the WC and BC components of the skill-ratio. A first noticeable fact to stress is that in the sample no up-skilling trend occurs during 1991-97, but rather a deskilling one: in fact, the average WC/BC ratio falls by 8%. Moreover, neither R&D activities are associated with an up-skilling trend: those firms which in 1989-91 performed R&D activities during 1991-97 show just a lower decrease of the WC/BC ratio (-6%), with respect to those without R&D (-12%); further, the only group showing an up-skilling trend is composed of the firms which have undergone some kind of organizational change, 1% of the total sample (cf. Piva and Vivarelli 2002a, p. 38). The regression analysis highlights a few points. First, the controls for the economic variables which traditionally feature in labour demand equations are significant with the expected signs: sales (positive), capital (positive, highlighting a capital-labour

[12]Obviously, these variables possess a loose explanatory power, being just dichotomic and qualitative (quantitative data were not available in the selected period): for example, technology is represented by a dummy of "R&D activity carried out in the 1989-91"; the same for organizational change and for globalization, which is captured by a dummy for outward foreign direct investment (FDI).

[13]Additionally, controls for size, sector technological intensity and takeovers/break-ups not involving employment changes are included.

complementarity), and wages (negative, and stronger for WC). Second, concerning the possible determinants of skill bias, only the dummy for organizational change is positive and significant, while neither technology (R&D activities) nor globalization seem to matter. In particular, the SUR estimation enables separate assessment of the impact of organizational change on WC and BC workers: while it is positive (but not significant) for WC, it is negative and significant (at 5% and 1% levels) for BC. The authors conclude suggesting that the insignificance of the R&D dummy does not rule out the SBTC hypothesis, since notoriously R&D-based variables are good innovative indicators mainly for technological leaders, which are committed to product innovations and demand increasingly skilled labour. Instead, as shown by the literature we shall recall in the next section, the same R&D variables do not represent satisfactorily the innovative activities of countries like Italy, focused on process innovations and - because of that - likely to experience mainly the labour saving impact of technological change, affecting particularly BC workers. While this interpretation of the lack of robust evidence of SBTC for Italy is worth to be further examined (see next sections), it is also important to notice that most of previous studies focused on Italy present a few methodological and econometric caveats which may crucially impinge on the empirical test of SBTC. Some of them have been already mentioned (e.g., too extensive a definition of "intangible assets" in Casavola et al. 1996, low informative power of the dummy "technological change" in Piva and Vivarelli 2002a,b), others - particularly relevant for the Italian case - will be discussed in the next section.

3 Main structural characteristics of the Italian economy

3.1 Overview

Italy is a "late comer" country and its recent path of economic development presents some peculiarities which differentiates the Italian experience from that of other similar European countries such as the UK, Germany and France. With the exception of a few "heavy" sectors (oil, steel, chemicals and some large-scale mechanics), whose take-off was heavily assisted by public intervention, most of the other manufacturing sectors (basically, consumer goods) were technologically backward and dimensionally inefficient, being largely fragmented and having an artisanal nature. This dualistic structure persisted well after the Second World War aftermath. Later, during the Seventies and the Eighties, most of these laggard sectors experienced a resurgence, later known as the "Third Italy" model of development, or the NEC (North-East-Centre) model (see Fuà, 1983, Pyke et al., 1990). The NEC model is characterized by local agglomerations of industrial activities (industrial districts), a dominant presence of small and medium enterprises (SME) and a specialization in traditional sectors (mainly textiles, footwear, clothing and furniture) and "light" mechanics (metal products and non-electrical machinery). The NEC model, also interpreted as a "flexible specialization" model (see Piore and Sabel, 1984), due to a complex system of institutional factors and financial constraints, has later influenced and downsized also the structure of the few truly "fordist" and scale-intensive sectors of the North-West area of the country (Barca and Magnani, 1989). Overall, several studies have shown that in Italy the typical innovative activity is represented by incremental product innovations (often mere restyling) and process innovations (see ISTAT 1995a, Santarelli and Sterlacchini, 1994, Sterlacchini, 1998); in particular, technological change embodied in process innovations represents the most important type of innovative activity carried out by traditional sectors, both in terms of innovative expenditures and turnover generated. At the same time, metal/machinery and traditional industries respectively register medium and low intensities of (formal intra-muros) R&D expenditures, and rely mainly on development, design and preproduction activities, often carried out externally or in joint-venture between committents and subcontractors. Consequently, due to the prevalence of traditional and small and medium enterprises within manufacturing, Italy as a whole features a low intensity of formal R&D - especially in its private business component (business enterprise research and development or BERD). Within this quota, basic research and truly radical inventions lack, while development (especially design and engineering) and preproduction activities prevail; moreover, a substantial portion of R&D activities has often a shared and informal character and in this way it is not even registered in business accounts and statistical datasets (see Santarelli and Sterlacchini, 1996). Obviously, the above features of the Italian innovation system shape profoundly also the demand for labour. Indeed, Italian manufacturing is also known as being a rather poor absorber of highly educated workers. These characters, which in the past decades were considered unavoidable and somehow physiologic for a "late comer" country, nowadays seem to be rather incompatible with the status of developed country. Considering that during the Nineties Italy has shown a strong persistence of its model of specialization (see De Benedictis and Tamberi, 2002), critics are claiming that the Italian model of development is no longer sustainable and is leading the country to a path of slow economic growth and low-tech productions, where international competition from the developing countries adversely impacts profits and wages. We now present in more details some of the above phenomena.

3.2 Employment and skill composition of the Italian economy

Table 1 shows the sectoral composition of Italian employment over the period 1995-2000.[14] First, in 2000, 22.3% of Italian workers is employed within manufacturing - it was 23.4% in 1995 (the corresponding figures for the US being 20.9% in 2000 and 23% in 1995, see OECD 2003a). Within manufacturing, traditional sectors (almost coincident with the sum of the first 5 II-digit sectors plus "furniture and musical instruments") account for 36.2% (it was 38.6% in 1995), and this sketches roughly the strong persistence of the Italian model of specialization; instead, in the US, their incidence is far much lower, being respectively 12.6% and 14%. Moreover, in 2000 another 25,6% of manufacturing is accounted for by metal-mechanical sectors (metals, metal products and non-electrical machinery), the second most significant constituent of the Italian model of specialization; for the US in 2000 it is 22.4%. Instead, the most high-tech and R&D intensive electro-mechanical sectors (electrical and electronic machinery, apparatus and equipment) in 2000 still account for just 9.3% of total manufacturing employment (14.4% in the US). Within services, we register the (surprising) decrease of employment in "Post and Telecommunications", affected negatively by the poor performance of Post due to public budget cuts, and the interesting increase of the weight of "Other business services", which within the macro-sector "Financial Intermediation, Real Estate and Business Services", experience a growth from 53.7% in 1997 to 60% in 2000.

Recent literature has confirmed that Italian industry, due to its dimensional structure based on small and medium firms, has a low absorptive capacity of highly skilled people. If we want to measure skills by educational attainment, we lack completely data at the firm level, except from episodic and case-study evidence. The only available alternative is to use individual surveys on people who got a University degree, like that run by ISTAT (1995b). Another example is the recently developed IPLAM survey (*Indagine sull'inserimento professionale dei laureati marchigiani*, see Staffolani and Sterlacchini, 2001), which has been monitoring the professional outcome of a sample of people who got an university degree from Universities located in the Marche Region, which provides a good example of the typical Italian industrial structure. The main result is that there is a certain mismatch between the contents offered in many educational programmes and the typical skills required by firms. In particular, non technical and non scientific degrees are in excess supply, while technical and scientific curricula, although highly demanded, often are not tailored at the skill needs of the many small and medium firms constituent of the Italian productive structure. The likely

[14]For the sake of synthesis, for manufacturing and services we present data aggregated 'almost' at the II digit. In fact, National Accounts statistics rarely allow a higher detail, while this source has the advantage of giving us the closest comparable indicator (number of total workers) to that provided by the Capitalia dataset used later.

Table 1: Total employment and sectoral distribution in Italy

Sectors	1995	1997	2000
Primary sector	**6.04**	**5.60**	**4.84**
Manufacturing	**23.37**	**22.93**	**22.30**
Manufacture of food products, beverages and tobacco	9.56	9.34	9.35
Manufacture of textiles	8.20	8.19	8.03
Manufacture of wearing apparel and fur	7.74	7.31	6.54
Manufacture of leather and leather products	4.62	4.61	4.23
Manufacture of wood and wood products	3.96	3.67	3.83
Traditional (these 5 above plus furniture and musical instruments)	*38.65*	*37.43*	*36.22*
Manufacture of pulp, paper and paper products	1.86	1.91	2.03
Publishing and printing	3.89	3.86	3.91
Manufacture of coke, refined petroleum products and nuclear fuel	0.50	0.48	0.51
Manufacture of chemicals, chemical products and man-made fibres	4.45	4.52	4.67
Manufacture of rubber and plastic products	3.63	3.87	3.98
Manufacture of other non-metallic mineral products	5.67	5.96	6.30
Manufacture of basic metals	2.97	2.92	3.16
Manufacture of fabricated metal products, except machinery and equipment	11.42	11.80	11.60
Manufacture of machinery and equipment n.e.c.	10.22	10.42	10.89
These 3 above	*24.62*	*25.15*	*25.66*
Manufacture of office machinery and computers	0.37	0.39	0.35
Manufacture of electrical, radio-TV and communication machinery and apparatus	6.60	6.76	6.77
Manufacture of medical, precision and optical instruments, watches/clocks	2.00	2.02	2.16
These 3 above	*8.98*	*9.17*	*9.27*
Manufacture of motor vehicles, trailers and semi-trailers	3.68	3.74	3.57
Manufacture of other transport equipment	2.21	2.15	2.09
Manufacture of furniture and musical instruments	4.58	4.30	4.24
Manufacture of jewellery, games, toys, miscellaneous and recycling	1.86	1.76	1.79
Electricity, gas and water supply	**0.75**	**0.71**	**0.64**
Construction	**6.63**	**6.55**	**6.48**
Trade, repairs, hotels and restaurants, transports and communication	**24.46**	**24.55**	**25.12**
Sale, maintenance and repair of vehicles; retail sale of automotive fuel	9.63	9.42	8.99
Wholesale and commission trade, except of vehicles	16.59	16.59	17.65
Retail trade, except of vehicles; repair of personal and household goods	37.50	37.14	35.75
Hotels and restaurants	17.01	16.99	18.16
Land transport; transport via pipelines	9.60	10.15	9.78
Water, air and ausiliary transport activities	4.49	4.73	5.04
Post and telecommunications	5.18	4.98	4.62
Financial intermediation, real estate, renting and business activities	**10.56**	**11.39**	**12.81**
Financial intermediation, except insurance and pension funding	17.49	15.84	13.60
Insurance and pension funding, except compulsory social security	2.18	1.90	1.58
Activities auxiliary to financial intermediation	7.54	7.15	6.65
Real estate activities and renting of machinery and equipment	7.12	6.41	5.80
Computer, research and related activities	12.01	11.73	12.42
Other professional and business activities	53.66	56.97	59.96
Other service activities	**27.98**	**28.08**	**27.63**
Public administration and defence; compulsory social security	23.32	22.48	21.75
Education	26.11	25.55	25.13
Health and social work	20.71	20.77	21.08
Recreational, cultural and sporting activities	4.50	4.67	5.44
Other services	9.78	9.82	10.17
Private households with employed persons	15.58	16.71	16.43
Entire economy (total number of workers)	**21,993**	**22,215**	**23,129**

All values in percentages. Values in bold refer to the "Entire economy"; values in Italics are sums of single "quasi-II" digit sectors; the other values refer to the own main (bold) aggregation Absolute values in thousands of "workers". Source: Our computations on National Accounts (see ISTAT, 2003a).

Table 2: Skill composition of the Italian economy by NACE 91 II-digit sectors - 2001

Sectors	WC/EMPL	BC/EMPL	WC/BC
Primary sector	**67.9**	**32.1**	**2.12**
Mining and oil extraction	**43.5**	**56.5**	**0.77**
Manufacturing	**40.1**	**59.9**	**0.67**
Manufacture of food products and beverages	45.2	54.8	0.83
Manufacture of tobacco	23.5	76.5	0.31
Manufacture of textiles	31.9	68.1	0.47
Manufacture of wearing apparel and fur	37.5	62.5	0.60
Manufacture of leather and leather products	28.6	71.4	0.40
Manufacture of wood and wood products	49.3	50.7	0.97
Manufacture of pulp, paper and paper products	29.5	70.5	0.42
Publishing and printing	60.3	39.7	1.52
Manufacture of coke, refined petroleum products and nuclear fuel	50.0	50.0	1.00
Manufacture of chemicals, chemical products and man-made fibres	56.1	43.9	1.28
Manufacture of rubber and plastic products	33.5	66.5	0.50
Manufacture of other non-metallic mineral products	37.5	62.5	0.60
Manufacture of basic metals	29.5	70.5	0.42
Manufacture of fabricated metal products, except machinery and equipment	36.9	63.1	0.58
Manufacture of machinery and equipment n.e.c.	39.6	60.4	0.66
Manufacture of office machinery and computers	63.4	36.6	1.74
Manufacture of electrical machinery and apparatus n.e.c.	43.8	56.3	0.78
Manufacture of Radio-TV and communication equipment and apparatus	52.8	47.2	1.12
Manufacture of medical, precision and optical instruments, watches/clocks	57.0	43.0	1.33
Manufacture of motor vehicles, trailers and semi-trailers	24.2	75.8	0.32
Manufacture of other transport equipment	39.4	60.6	0.65
Manufacture of furniture; manufacturing n.e.c	42.9	57.1	0.75
Recycling	44.9	55.1	0.81
Electricity, gas and water supply	**58.7**	**41.3**	**1.42**
Construction	**46.3**	**53.7**	**0.86**
Business services	**72.0**	**28.0**	**2.58**
Sale, maintenance and repair of vehicles; retail sale of automotive fuel	64.3	35.7	1.80
Wholesale and commission trade, except of vehicles	75.5	24.5	3.08
Retail trade, except of vehicles; repair of personal and household goods	73.4	26.6	2.76
Hotels and restaurants	55.0	45.0	1.22
Land transport; transport via pipelines	55.6	44.4	1.25
Water transport	47.4	52.6	0.90
Air transport	79.4	20.6	3.85
Supporting and auxiliary transport activities; activities of travel agencies	68.1	31.9	2.14
Post and telecommunications	80.2	19.8	4.06
Financial intermediation, except insurance and pension funding	97.4	2.6	37.03
Insurance and pension funding, except compulsory social security	97.9	2.1	46.33
Activities auxiliary to financial intermediation	100.0	0.0	
Real estate activities	97.6	2.4	41.00
Renting of machinery and equipment; of personal and household goods	75.7	24.3	3.11
Computer and related activities	93.9	6.1	15.51
Research and development	94.5	5.5	17.17
Other professional and business activities	72.6	27.4	2.65
Public and personal services	**78.9**	**21.1**	**3.75**
Public administration and defence; compulsory social security	83.6	16.4	5.11
Education	87.8	12.2	7.18
Health and social work	74.4	25.6	2.91
Sewage and refuse disposal, sanitation and similar activities	38.1	61.9	0.62
Activities of membership organizations n.e.c.	86.8	13.2	6.59
Recreational, cultural and sporting activities	82.3	17.7	4.65
Other service activities	66.3	33.7	1.97
Private households with employed persons	21.5	78.5	0.27
Extra-territorial organizations and bodies	86.2	13.8	6.22
Entire economy	**64.3**	**35.7**	**1.80**

Source: Our computations on LFS data (unpublished, see ISTAT 2003b).

result is an over-education outcome, since among those people who were occupied 5 years after the graduation, 40% have a work profile for which the degree was unnecessary (see Staffolani and Sterlacchini, 2001, p. 216). Moreover, other evidence confirms the ongoing crisis of Italian technical secondary school, who seem unable to match the skill requirements of an important part of Italian industry (basically electromechanics and metalworking industry, and particularly in ICT-related jobs, see Federcomin, 2002). However, this evidence lacks a suitable sectoral disaggregation and for that we need to refer to other sources. Another possible option is offered by the Labour Force Survey -(*Indagine Trimestrale sulla Forza Lavoro*). Table 2 shows the skill composition of Italian workers, disaggregated by industry.[15]

Although the skill indicator used has some limitations,[16] there are some stylized facts which stand out clearly. The first is that the skill-ratio (WC/BC) is far higher in the service sector - particularly in business services - than in manufacturing: while in the first the majority share is that of WC, in manufacturing the BC prevail (accounting for around 60% of total employment). Moreover, both within services and manufacturing, some sectors are clearly at the frontier of the skill-intensity. Among business services, Financial intermediation, Insurance and Pension funding, Real Estate, Computer services and R&D services have a share of WC larger than 90% of total employment. Among manufacturing, Publishing and Printing, Manufacture of Coke and others, Chemicals, Office Machinery and Computers, Radio, Television and Communication Sets, Medical and Precision Instruments have a share of WC equal or higher than 50%.

3.3 R&D, innovation and ICT in the Italian economy

Concerning R&D-related indicators, a first broad evidence is presented by table 3. Italian economy has always been characterized by a low intensity of formal R&D activity, and this feature persisted over the last decade. Both with respect to the US leader and the EU average, the Italian intensity of R&D activity falls well behind.

In particular, as concerns the overall R&D (GERD, "Gross Domestic Expenditure on R&D", which includes public and privately funded and carried out R&D), the Italian gap with respect to the EU average has slightly reduced over the last 20 years: nevertheless, it remains wide, being the Italian

[15]Unfortunately, disaggregated data for the previous periods are not available, so that a diachronic appraisal is impossible.

[16]In particular, the variable WC includes entrepreneurs and their family members working within the firm and this overestimates the skill-ratio in sectors where small-size and family-owned businesses prevail. Moreover, most clerical workers in services are low-skilled, while a non-negligible share of shop-floor workers has upper-secondary schooling. These facts are not accounted for by our classification, which considers simply the occupational position. However, our subsequent analysis will focus on manufacturing industry and we believe that within this sector our indicator is a fairly good approximation of workers' actual skill endowment.

Table 3: R&D indicators across countries

	Year									
	1981	1985	1990	1995	1996	1997	1998	1999	2000	2001
GERD/GDP - %										
US*	2.34	2.8	2.7	2.5	2.6	2.6	2.6	2.7	2.7	2.8
European Union	1.69	1.9	1.9	1.8	1.8	1.8	1.8	1.9	1.9	1.9
Italy	0.88	1.1	1.3	1.0	1.0	1.1	1.1	1.0	1.1	..
Italy/EU	52.1	60.2	66.5	55.6	56.1	58.3	59.1	55.9	56.6	
BERD/Industry Value Added - %										
US*	2.25	2.76	2.7	2.56	2.64	2.68	2.69	2.72	2.77	2.85
European Union	1.44	1.66	1.78	1.61	1.62	1.63	1.64	1.73	1.77	1.79
Italy	0.64	0.84	1.04	0.74	0.75	0.73	0.72	0.72	0.75	0.79
Italy/EU	44.4	50.6	58.4	46.0	46.3	44.8	43.9	41.6	42.4	44.1
Business Enterprise researchers per thousand industrial employment										
US	6.6	8.1	8.6	8.6	9.2	9.6	9.9	10.1	10.2	..
European Union	2.3	2.8	..	3.5	3.6	3.7	3.8	4	4.1	..
Italy	1.2	1.5	1.9	1.7	1.7	1.7	1.7	1.6	1.6	..
Italy/EU	52.2	53.6	.	48.6	47.2	45.9	44.7	40.0	39.0	.
Total Business Enterprise R&D personnel per thousand industrial employment										
US	..	..	..	..	..	..	..	..	..	..
European Union	7	7.6	..	7.7	7.7	7.8	7.9	8.1	8.1	..
Italy	3	3.4	4	3.8	3.8	3.8	3.8	3.6	3.8	..
Italy/EU	42.9	44.7	.	49.4	49.4	48.7	48.1	44.4	46.9	.

*Underestimated since it excludes most or all capital expenditure.

Source: Our computations on OECD (2003b).

GERD intensity only 56.6% of the EU one still in 2000. With respect to the business sector R&D (BERD, "Business Expenditure on R&D"), the gap has even worsened, since the time trend seems to point to a reduction below the 1981 level: in 2001, Italian BERD is just 44.1% of the EU one. The situation does not change significantly if we consider the indicator "Business Enterprise researchers" or that "Total Business Enterprise R&D personnel" - both of them are weighted for total industrial employment. The first indicator suggests that in Italy over the last 20 years the number of people devoted within firms to high-level research tasks has significantly reduced; the second indicator considers all those performing R&D activities (not just research) and reports that their 2000 figure has fallen below the level of the mid-Nineties. Obviously, behind the low Italian BERD there are two main factors: the Italian specialization in traditional and mechanics sectors, which are respectively low and medium R&D intensive sectors, and the decline of Italian firms in R&D-intensive sectors, such us pharmaceuticals, computers, electronics, precision instruments, aerospace and others. These features are evident in table 4, which reports the BERD sectoral disaggregation for Italy and the US.

As to BERD intensity, Italy has a negative gap with respect to the US both in manufacturing and services.[17] For manufacturing, a further breakdown is presented in table 4. Also within each macrosector, it is a common situation to find a disadvantage for Italy. Within manufacturing, strong R&D performers are Chemicals, Office Machinery, Radio-TV equipment, Medical instruments, Motor vehicles and Other Transport equipment (especially Aircraft): for all these industries, with the exception of Radio-TV equipment and Aircraft,[18] the Italian figures are substantially inferior to the US ones. Also in services, the Italian intensity appears particularly inferior in Financial Intermediation and Computer services, a fact which can be partly traced back to the Italian despecialisation of computer manufacturing.

Finally, we come to examine the Italian position concerning ICT investment. Table 5 shows the yearly ICT investment of firms, disaggregated into its main components (IT hardware, IT software, communication equipment). Table 5 expresses ICT intensity over GDP, both measured in constant terms to reflect quality and price changes. A first noticeable evidence is that ICT intensity is particularly low in Italy, which still in 2001 falls behind the EU average; the distance with the US leader is even wider. Moreover, the Italian gap is even higher if we consider strict IT expenditures, both hardware and software, where the Italian intensity is almost half of the EU one. In other words, the Italian digital gap is particularly evident in IT, while in Communication technologies the Italian intensity is higher than the EU average.

[17]Over three-quarters of the overall BERD expenditure in Italy are accounted for by the manufacturing sector. Among the share accounted for by services, business service sectors perform the main part, see ISTAT (2002).

[18]Nevertheless, we know already that both industries in Italy maintain a very small relevance in terms of output and employment, being in decline.

Table 4: Ratio of R&D expenditure on value-added by sector - Italy and US

Sectors	Italy						US	
	1995	**1996**	**1997**	**1998**	**1999**	**2000**	**1995**	**2000**
TOTAL MANUFACTURING	**2.21**	**2.31**	**2.24**	**2.00**	**2.12**	**2.15**	**8.09**	**8.52**
Food products, beverages and tobacco	0.35	0.34	0.30	0.38	0.34	0.34	1.15	1.07
Textiles, textile products, leather and footwear	0.07	0.07	0.08	0.07	0.05	0.05	0.69	0.51
Wood, paper, printing, publishing	0.11	0.07	0.09	0.10	0.09	0.09	1.10^a	1.57
Chemical, rubber, plastics and fuel products	3.04	3.18	2.99	2.92	2.92	3.26	9.13	9.05
........Chemicals excluding pharmaceuticals	2.50	3.09	2.94	2.87	2.71	2.76	6.89	7.95
........Phamaceuticals	9.73	8.17	7.96	8.19	6.71	6.98	23.51	20.19
Other non-metallic mineral products	0.17	0.16	0.14	0.15	0.10	0.11	1.38	2.18
Basic metals	0.65	0.77	0.89	0.38	0.39	0.29	1.12	1.24
Fabricated metal products, except machinery and equipment	0.36	0.56	0.12	0.14	0.16	0.17	1.17	1.77
Machinery and equipment, instruments and transport equipment	6.21	6.41	6.23	5.39	5.82	5.69	16.30	16.42
....Machinery and equipment, n.e.c.	1.34	1.31	2.70	1.76	1.69	1.65	4.63	5.51
....Office, accounting and computing machinery	24.47	35.23	16.52	7.02	7.37	8.62	28.94	30.70
....Electrical machinery and apparatus, n.e.c.	2.88	3.21	1.82	1.83	1.41	1.45	8.86	9.62
....Radio, television and communication equipment	20.82	19.62	20.72	21.46	27.87	18.46	15.14	18.56
....Medical, precision and optical instruments	3.20	2.56	4.83	3.54	3.42	3.46	25.39	30.21
....Motor vehicles, trailers and semi-trailers	10.35	10.92	8.77	8.73	8.64	11.14	15.27	15.43
....Other transport equipment	14.58	17.32	13.21	10.85	14.43	10.83	36.56	17.51
........Aircraft and spacecraft	29.38	35.01	26.08	22.38	31.48	24.42	45.73	20.76
Furniture; manufacturing n.e.c.	0.25	0.24	0.22	0.20	0.12	0.12	-	-
ELECTRICITY, GAS AND WATER SUPPLY	**0.66**	**0.61**	**0.40**	**0.65**	**0.50**	**0.04**	**0.21**	**0.07**
CONSTRUCTION	**0.02**	**0.03**	**0.03**	**0.04**	**0.04**	**0.03**	**-**	**0.05**
TOTAL SERVICES	**0.09**	**0.10**	**0.11**	**0.17**	**0.15**	**0.16**	**$0{,}52^b$**	**0.92**
Wholesale and retail trade; repairs	0.01	0.01	0.02	0.02	0.02	0.02	-	1.47
Hotels and restaurants	0.00	0.00	0.00	0.00	0.00	0.00	-	-
Transport and storage	0.02	0.02	0.01	0.01	0.01	0.01	-	0.09
Financial intermediation	0.00	0.00	0.09	0.11	0.10	0.11	-	0.47^c
Real estate, renting and business activities	0.28	0.28	0.33	0.53	0.47	0.49	-	-
....Computer and related activities	12.03^d	10.93^d	17.00^d	15.30^d	15.22^d	12.79^d	23.09^d	21.58^d
....Research and development	60.31^d	54.63^d	47.92^d	62.33^d	64.67^d	65.51^d	16.45^d	20.45^d
....Other business activities	0.09^c	0.13^c	0.20^c	0.16^c	0.14^c	0.17^c	-	-
Community, social and personal services	0.01	0.01	0.01	0.01	0.01	0.01	-	-
TOTAL (M+E+C+S)	**0.59**	**0.59**	**0.58**	**0.57**	**0.57**	**0.57**	**1.84**	**2.06**

^{a}, ^{b}, ^{c} = Figures are not strictly comparable since: ^{a}includes R&D of Furniture; ^{b}includes R&D of others sectors; ^{c}includes R&D of Real estate and Renting d = Lacking their own VA, to allow comparison R&D figures have been referred to Total Services VA, both for Italy and the US Source. Our computations on OECD (2002, 2003a).

Table 5: ICT Investment on GDP (%) across time and countries - Breakdown by components

Year	**IT hardware**			**Communication**			**IT Software**			**ICT (total)**		
	USA	**EU - 14**	**Italy**	**USA**	**EU - 14**	**Italy**	**USA**	**EU - 14**	**Italy**	**USA**	**EU - 14**	**Italy**
1980	0.19	0.10	0.06	0.78	0.40	0.42	0.26	0.14	0.09	1.23	0.65	0.58
1985	0.56	0.35	0.21	0.90	0.49	0.49	0.51	0.38	0.23	1.96	1.22	0.93
1990	0.65	0.60	0.34	0.88	0.63	0.76	0.90	0.72	0.50	2.43	1.95	1.60
1991	0.68	0.63	0.36	0.83	0.64	0.81	1.01	0.74	0.51	2.52	2.01	1.68
1992	0.82	0.63	0.38	0.82	0.65	0.82	1.11	0.81	0.53	2.75	2.09	1.74
1993	0.97	0.65	0.29	0.80	0.66	0.81	1.20	0.84	0.51	2.96	2.15	1.61
1994	1.07	0.77	0.37	0.87	0.68	0.87	1.25	0.90	0.53	3.19	2.36	1.78
1995	1.38	0.94	0.47	0.96	0.75	0.94	1.33	0.96	0.57	3.66	2.64	1.99
1996	1.75	1.22	0.63	1.03	0.81	1.03	1.48	1.05	0.63	4.26	3.09	2.30
1997	2.20	1.57	0.83	1.10	0.87	1.27	1.75	1.14	0.64	5.05	3.58	2.74
1998	2.79	2.22	1.10	1.22	0.97	1.33	2.07	1.39	0.75	6.08	4.58	3.18
1999	3.39	2.87	1.49	1.40	1.03	1.43	2.29	1.48	0.85	7.08	5.39	3.77
2000	3.74	3.50	1.86	1.72	1.16	1.50	2.38	1.55	0.92	7.85	6.21	4.28
2001	3.70	3.98	2.15	1.40	1.14	1.55	2.40	1.57	0.88	7.50	6.69	4.57

Source: Our computations on Groningen G&D Centre data (`http://www.ggdc.net/index-dseries.html#top`) for ICT Investments; OECD (2003a) for GDP at constant terms.

Going into more details, table 6 presents ICT investment intensity (over value added) over the period 1998-2000. These data, which have started to be available only recently, present a high degree of consistency, since are not simply producers' estimates but are directly collected at the firm-level by a (mostly) census survey carried out by ISTAT. Moreover, data are disaggregated up to the II digit, and this provides a more accurate account for an indicator which presents an important degree of sectoral variability, not satisfactorily expressed by a higher level of disaggregation.

As stands clear from table 6, concerning ICT intensity, the behaviour of manufacturing and services is reverted. While in R&D intensity manufacturing largely surpasses services, in the ICT intensity the former lags behind the latter. Within manufacturing, the highest ICT intensities are registered in Printing and Publishing, Office Machinery and Radio-TV equipment; however, at least for the latter two sectors, this also reflects their higher technological opportunities. Within services, high intensity are registered in Wholesale trade, Renting of machinery, Computer and related services, R&D services, Other business activities (including professional services), Education and Cultural activities.

4 Data description

We use in our empirical analysis data from the Survey of Italian Manufacturing (*Indagine sulle imprese manifatturiere*, SIM hereafter) managed by the Capitalia Banking Group. As the name suggests information is collected on manufacturing firms only. The survey gathers information on all firms with more than 500 employees and a representative sample of firms with more than 11 and less than 500 employees.[19] Since the survey is repeated over time at three-year intervals, in each wave a part of the sample is kept fixed (rotating panel) while the other part is completely renewed. This helps to analyse both variations over time for the same firms and 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, after removing firms undertaking break-ups or take-overs in the second wave and firms with missing variables the panel size is reduced to 832 firms (825 when considering the detail of R&D and ICT expenditures by destination and type, respectively). 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 panel. The descriptive statistics are reported in table 7.

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

Table 6: ICT investment intensities over value added (%) by sector, 1998-2000

Sectors	**1998**	**1999**	**2000**	**1998-2000**
Mining	**0.13**	**0.15**	**0.24**	**0.18**
Manufacturing	**0.73**	**0.65**	**0.60**	**0.66**
Manufacture of food products and beverages	0.50	0.52	0.48	0.50
Manufacture of tobacco	0.18	0.24	0.03	0.15
Manufacture of textiles	0.48	0.43	0.37	0.43
Manufacture of wearing apparel and fur	0.53	0.58	0.63	0.58
Manufacture of leather and leather products	0.50	0.93	0.31	0.58
Manufacture of wood and wood products	0.80	0.48	0.78	0.69
Manufacture of pulp, paper and paper products	0.37	0.42	0.38	0.39
Publishing and printing	1.24	1.24	1.68	1.40
Manufacture of coke, refined petroleum products and nuclear fuel	0.32	0.89	0.97	0.74
Manufacture of chemicals, chemical products and man-made fibres	0.68	0.50	0.43	0.53
Manufacture of rubber and plastic products	0.58	0.49	0.47	0.51
Manufacture of other non-metallic mineral products	0.44	0.34	0.42	0.40
Manufacture of basic metals	0.36	0.47	0.30	0.37
Manufacture of fabricated metal products, except machinery and equipment	0.67	0.66	0.53	0.62
Manufacture of machinery and equipment n.e.c.	0.72	0.60	0.79	0.71
Manufacture of office machinery and computers	7.92	7.76	1.07	6.63
Manufacture of electrical machinery and apparatus n.e.c.	0.85	0.63	0.61	0.69
Manufacture of Radio-TV and communication equipment and apparatus	2.15	0.79	1.14	1.33
Manufacture of medical, precision and optical instruments, watches/clocks	0.82	0.85	0.58	0.74
Manufacture of motor vehicles, trailers and semi-trailers	0.50	0.32	0.23	0.35
Manufacture of other transport equipment	1.02	0.79	0.85	0.89
Manufacture of furniture; manufacturing n.e.c	0.76	0.55	0.50	0.60
Recycling	0.53	0.52	0.41	0.48
Electricity, gas, steam and water supply	**0.15**	**0.21**	**0.21**	**0.19**
Construction	**0.37**	**0.44**	**0.34**	**0.38**
Services[a]	**0.71**	**0.85**	**0.89**	**0.82**
Sale, maintenance and repair of vehicles; retail sale of automotive fuel	0.49	0.79	0.56	0.61
Wholesale and commission trade, except of vehicles	0.92	1.07	1.15	1.05
Retail trade, except of vehicles; repair of personal and household goods	0.57	0.62	0.59	0.59
Hotels and restaurants	0.30	0.44	0.39	0.38
Land transport; transport via pipelines	0.26	0.32	0.27	0.28
Water transport	0.19	0.17	0.15	0.17
Air transport	0.58	0.74	0.80	0.66
Supporting and auxiliary transport activities; activities of travel agencies	0.51	0.73	0.70	0.66
Post and telecommunications	0.02	0.70	0.96	0.56
Real estate activities	0.32	0.29	0.42	0.34
Renting of machinery and equipment; of personal and household goods	1.23	1.21	5.33	2.65
Computer and related activities	2.55	2.84	2.29	2.55
Research and development	0.87	1.05	1.59	1.20
Other professional and business activities	1.08	1.27	1.04	1.13
Education	0.75	1.31	1.41	1.16
Health and social work	0.71	0.46	0.71	0.63
Sewage and refuse disposal, sanitation and similar activities	0.42	0.30	0.52	0.43
Recreational, cultural and sporting activities	1.17	0.64	1.44	1.10
Other service activities	1.14	0.76	0.45	0.77
Total	**0.67**	**0.72**	**0.71**	**0.70**

Source: Our computations on Survey on Firms Accounts, (unpublished data, see ISTAT, 1997). [a] Services exclude Financial intermediation, insurance and pension funding since data were not available.

Table 7: Panel and wave 1995-1997 descriptive statistics

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 Suppliers (%)	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
Average investiments 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
Skill ratio[b]		
1995	0.74	0.61
1996	0.75	0.60
1997	0.76	0.59

continue

Table 7 - continue

Variable	1995-97 wave	Panel
Rate of change of WC^c 1997-2000 (%)	-	9.09
by Pavitt sector:		
Supplier Dominated	-	9.53
Scale Intensive	-	8.52
Specialized Suppliers	-	8.01
Science Based	-	14.58
Rate of change of BC^c 1997-2000 (%)	-	2.92
by Pavitt sector:		
Supplier Dominated	-	1.64
Scale Intensive	-	7.86
Specialized Suppliers	-	2.21
Science Based	-	0.95

Notes. [a] Millions of current Italian lira. [b] Ratio between non production and production workers. [c]WC: white collars (non-production workers); BC: blue collars (production workers).

This table shows the composition and means for some selected characteristics of the panel and the 1995-1997 wave of the SIM.

The distribution of firms by number of employees and geographic area is very similar in the panel and the 1995-1997 wave. The average amount of sales[20] is 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 and the skill-ratio are lower in the panel. In the panel, Supplier Dominated sectors are over-represented and Scale Intensive sectors under-represented, like the distribution by the Pavitt[21] 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, we think that the panel can be considered as fairly representative of the 1995-1997 wave over several dimensions (firm geographical location, 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 amount of average capital stock and sales and a lower skill ratio with respect to firms included in the 1995-1997 wave.

As to the panel, table 7 shows that both non production (WC) and production workers (BC) experienced a positive growth in the period 1997-2000, to which the dependent variables (the skill-ratio and the rates of change of WC and BC, see the next section) of our empirical analysis refer. In particular, the growth of WC has been more sustained than that of BC workers and as a consequence the skill ratio has increased. The increase has been particularly marked in the Science Based sector and negligible in the Scale Intensive sector.

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

[21]See Pavitt (1984).

5 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 for wage-bill-share equations also in the estimation of employment-share equations. Here, we follow their approach. In this context SBTC is defined as an increase in the non production/production workers ratio due to an increase in the stock of technology that firms use.

We define $SHARE$ as the ratio of the number of non production (NP) workers on the number of production (P) workers within a firm. We call $SHARE$ the skill-ratio. In our specification the skill-ratio depends on the tangible capital stock K (in natural logarithm), the amount of sales Y (in natural logarithm),[22] the wage ratio between P and NP workers W^{NP}/W^{P}(in natural logarithm), some proxies for the firm's degree of 'technological intensity' or stock of 'technological capital' ($TECH$) and a firm specific fixed effect u_i constant over time:

$$SHARE_{it} = \phi + \kappa t + \alpha ln(K_{it}) + \beta ln(Y_{it}) + \gamma TECH_{it} + \delta ln(W^{NP}_{it}/W^{P}_{it}) + u_i + \epsilon_{it} \quad (1)$$

where i and t are subscripts for firms and time, respectively, α is a measure of cross-firm average bias in technological change and ϵ_{it} is a random error term. In this specification the 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.[23] If there are omitted factors affecting both $R\&D$ or ICT and the skill-ratio, then the estimates of γ would be biased. The second problem is due to the fact that γ may simply reflect correlation rather than causation: is it the stock of technology that affect 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, and obtaining the following specification:

$$\Delta_3 SHARE_{it} = \kappa + \alpha\Delta_3 ln(K_{it}) + \beta\Delta_3 ln(Y_{it}) + \gamma\Delta_3 TECH_{it} + \delta\Delta_3 ln(W^{NP}_{it}/W^{P}_{it}) + v_{it} \quad (2)$$

where $v_t = \epsilon_{it} - \epsilon_{it-3}$. Here we have considered long differences, namely three-year differences. In analogy with Machin and Van Reenen (1998), we

[22] Sales are evaluated in million of 1995 Italian lira.

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

first used as a proxy for the change in the stock of technology the ratio of $R\&D$ and ICT expenditures on Y. We also considered alternative measures of $R\&D$ or ICT 'intensity' of firms, such as the amount of $R\&D$ and ICT per worker in the three years before $\Delta_3 SHARE$ is observed. While the former measures are sensitive to the degree of 'externalisation' and 'tertiarisation' of a firm, the latter should be less affected by such phenomena. Time differencing equation (1) removes the persistent component in the error term (i.e. the firm specific effect u_i), which may be correlated with persistent proxies for the variation in 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 $\Delta_3 TECH_{it}$.[24]

Since two recent waves of the SIM are available, we have different options about the period on which to focus our analysis. We decide to consider the variation of the skill-ratio occurred between 1997 and 2000. This enables us to use the lagged expenditures on $R\&D$ 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 refers to the 1997-2000 period. This also contributes to avoiding the problem of the 'double counting' of $R\&D$ personnel.[25]

Like many other authors,[26] we decided to omit from the analysis the wage ratio. This is done for two main reasons. Firstly, wages are not provided by the survey and need to be imputed from other sources. However, matching different data sets usually requires some strong assumptions and a certain level of discretionality on the part of the researcher that we preferred to avoid at this stage of the analysis. Secondly, the wage ratio is likely to be endogenous.[27]

[24] 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. Chennels and Van Reenen (1999) suggest the use of instrumental variables (IV) to solve the problem but notice how the standard approach of using lags has not been often used since lagged values of stocks are likely to be weak instruments for variations in highly persistent expenditures, such as those in $R\&D$. As we said we did not use IV but lagged values for both $R\&D/Y$ and ICT/Y. When using contemporaneous not instrumented values for ICT/Y the results were not significantly different.

[25] The problem arises when considering the variation in $SHARE$ and $R\&D$ expenditures in the same period. In that case a positive correlation between $SHARE$ 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 $R\&D$ expenditures relate to personnel costs).

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

[27] 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

After estimating equation (2), we decided to estimate the impact of the same explanatory variables on the rates of change of the stocks of skilled and unskilled workers, respectively. In particular we estimated the following system of simultaneous equations using SUR methods:

$$\begin{aligned} \Delta_3 l_{it}^{BC} &= \kappa_{WC} + \alpha_{WC}\Delta_3 ln(K_{it}) + \beta_{WC}\Delta_3 ln(Y_{it}) + \gamma_{WC}\Delta_3 TECH_{it} + \nu_{1it} \\ \Delta_3 l_{it}^{WC} &= \kappa_{BC} + \alpha_{BC}\Delta_3 ln(K_{it}) + \beta_{BC}\Delta_3 ln(Y_{it}) + \gamma_{BC}\Delta_3 TECH_{it} + \nu_{2it}. \end{aligned} \tag{3}$$

where l_{it}^{BC} and l_{it}^{WC} are the stocks of non-production (white collars) and production (blue collars) workers in logarithms, respectively. The two levels of analysis provide different information. The study of the change in the skill-ratio can provide useful information on the direction of the skill bias. However, suppose that we find evidence of a positive effect of technology on the skill-ratio, the first type of analysis (on the employment share) does not shed light on the impact on the single components of the employment share. The positive effect on the skill-ratio may be the result of the reduction of unskilled workers only, the increase of skilled workers only, a faster increase of skilled workers, or a simultaneous increase of skilled and reduction of unskilled workers. In this respect, the second type of analysis on the rate of change of the stock of both components of employment, skilled and unskilled, is more informative.

6 Results

6.1 Changes in employment share

As we said, we estimate the variation in $SHARE$ occurred between 1997 and 2000, which is our dependent variable, as a function of the variation in capital stock (in natural logarithm), the variation in turnover (in natural logarithm), and some proxies of firms' $R\&D$ and ICT intensity.

Table 8 shows our estimates. Variations in (ln) capital and turnover refer to the 1997-2000 period, 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 two kinds of measures of firms' $R\&D$ and ICT intensity. The first measure is the amount of total 1995-1997 expenditures on total 1995-1997 turnover,[28] the second is the amount of 1995-1997 $R\&D$ and ICT divided by the average

through the degree of complementarity of technology with each type of workers. However, wage dynamics are likely to be determined by the $R\&D$ and ICT more at the economy aggregate level than at firm level, and the second channel is likely to dominate. 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).

[28]Used for instance in Machin and Van Reenen (1998).

Table 8: Change in employment share (OLS)

Variable	I			II		
	Coef.		s.e.	Coef.		s.e.
dln(K)	-0.05		0.04	-0.05		0.04
dln(Y)	-0.34	***	0.08	-0.34	***	0.08
(R&D/Y)	1.41		1.80	-		-
(ICT/Y)	7.84		5.55	-		-
(R&D/N)	-		-	0.01		0.01
(ICT/N)	-		-	0.00		0.00
constant	0.03		0.04	0.03		0.04
N. observations	832			832		
Adjusted R^2	0.02			0.03		
Wald test (p-value)	6.26 (0.00)			5.96 (0.00)		
White het. test (p-value)	18.61 (0.18)			16.93 (0.26)		

Notes: *** significant at 1%, ** significant at 5%, * significant at 10%. P-values are reported in brackets. The table reports the Wald test for the joint significance of all regressors (except the constant) and the White test for heteroskedasticity of unspecified form. In early specifications we also included firm size (in discrete classes) and geographic location but the two variables were not significant. The p-values for firm size was 0.99 in both the specifications I and II while the p-values for geographic location were 0.50 for the first specification and 0.67 for the second. On the grounds of this evidence firm size and location were also excluded from the following regressions.

number of workers in the firm in the same period, measured in millions of 1995 Italian lira. The latter is likely to be less sensitive to the degree of tertiarisation and externalisation of a firm.

From table 8 we notice that in qualitative terms the results of the regressions using the two measures are very similar, although the overall fit slightly increases when considering *R&D* and *ICT* per worker.[29] The variance explained by the covariates is very low and only the variation in turnover is statistically significant (at 1%) with a negative sign.[30] An increase in turnover is correlated with a reduction in *SHARE*. This also emerges from other studies estimating employment-share equations[31] implying that in the short-run an increase in turnover ('production' in a standard production function

[29]The estimation sample consists of all firms for which the necessary variables are non-missing. We dropped from the sample one firm with an exceptionally high value in the change of *SHARE* and *R&D/Y* with respect to the sample average. When including this observation the estimated coefficient of *R&D/Y* was 15.7 with a t-value of 7.3 (for this observation the Studentized residual turned out to be 22.4).

[30]The low explanatory power of the regression is partly due to the fact that we use a long-differences approach. In cross-section studies the explanatory power is likely to be higher since recently constituted (especially small) firms (which enter the second wave of the SIM and are excluded from the panel) are likely to be more technologically advanced and employ a higher ratio of skilled workers as compared to old and large firms (which appear in both waves of the SIM). However, as we already stressed, cross-section studies do not allow to take into account potential problems of firms' unobserved heterogeneity (i.e. firms' fixed effects) and the endogeneity of technological variables with respect to the workforce skill composition.

[31]See for instance Machin and Van Reenen (1998, p. 1243).

Table 9: Change in employment share - with Pavitt sectors interaction terms (OLS)

Variable	Coef.		s.e.
dln(K)	-0.04		0.04
dln(Y)	-0.31	***	0.08
(R&D/Y)	12.10	***	3.20
(R&D/Y)*Scale I.	-29.94	***	6.61
(R&D/Y)*Specialized S.	-14.26	***	4.00
(R&D/Y)*Science B.	12.27		12.14
(ICT/Y)	2.23		10.20
(ICT/Y)*Scale I.	26.36		16.04
(ICT/Y)*Specialized S.	-1.88		12.84
(ICT/Y)*Science B.	31.68		36.93
Scale Intensive	-0.04		0.08
Specialized Suppliers	0.04		0.07
Science Based	-0.28		0.21
Constant	0.03		0.05
N. observations	832		
Adjusted R^2	0.06		
Wald test (p-value)	4.85 (0.00)		
White het. test (p-value)	35.98 (0.93)		

Notes: *** significant at 1%, ** significant at 5%, * significant at 10%. P-values are reported in brackets. Supplier Dominated sectors are the reference category. The table reports the Wald test for the joint significance of all regressors (except the constant) and the White test for heteroskedasticity of unspecified form.

approach) requires a higher proportion of production workers. This effect is robust to both specifications of firms' technological intensity. Capital is never statistically significant. This might be due to the poor quality of our measure of the capital stock which is derived from balance sheet data and it is evaluated at the net 'historical cost'.[32] For this reason, we estimated the models in table 8 also using the natural logarithm of the real value (in millions of 1995 Italian lira) of the investment flows in the period 1995-1997 and the results were not significantly different.[33] Neither *R&D* nor *ICT* intensities are significant in explaining the variation in the skill-ratio.

In order to deepen our analysis, we included also dummies for the type of industry according to the Pavitt's (1984) classification (the reference are Supplier Dominated sectors) and interaction terms between these dummies and *R&D* and *ICT* measures. The results are show in table 9. Although the results on the effect of *ICT* do not change, on the contrary the effect of *R&D* becomes statistically significant. In particular, *R&D* expenditures

[32] It is the 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.

[33] The results are not reported here for the sake of brevity but are available upon request from the authors.

Table 10: Change in employment share - with Pavitt sectors interaction terms (OLS)

Variable	Coef.		s.e.
dln(K)	-0.04		0.04
dln(Y)	-0.26	***	0.08
(R&D/N)	0.01	**	0.00
(R&D/N)*Scale I.	-0.05	***	0.01
(R&D/N)*Specialized S.	-0.01	**	0.00
(R&D/N)*Science B.	0.03	*	0.01
(ICT/N)	0.00		0.01
(ICT/N)*Scale I.	0.04	*	0.02
(ICT/N)*Specialized S.	0.00		0.02
(ICT/N)*Science B.	0.00		0.04
Scale Intensive	-0.02		0.08
Specialized Suppliers	0.03		0.07
Science Based	-0.17		0.18
Constant	0.04		0.05
N. observations	832		
Adjusted R^2	0.06		
Wald test (p-value)	5.22 (0.00)		
White het. test (p-value)	31.43 (0.98)		

Notes: *** significant at 1%, ** significant at 5%, * significant at 10%. P-values are reported in brackets. Supplier Dominated sectors are the reference category. The table reports the Wald test for the joint significance of all regressors (except the constant) and the White test for heteroskedasticity of unspecified form.

have a positive effect on the skill-ratio in the Supplier Dominated industries, while they have a negative impact in Scale Intensive and Specialized Suppliers industries, the effect being weak in the latter case. The magnitude of a one percent point increase in the $R\&D/Y$ and ICT/Y ratios are +0.12, -0.18 and -0.02 for Supplier Dominated, Scale Intensive and Specialized Suppliers industries, respectively. The absence of a statistically significant effect for the Science Based industries is probably due to the very low number of such firms present in the estimation sample. The same results are confirmed in the second kind of specification in table 10 using $R\&D$ and ICT per worker and in this case $R\&D$ expenditures become marginally significant also for firms operating in Science Based sectors, where the effect is also the biggest.

In principle, ICT and $R\&D$ could be a complement or a substitute for skilled labour, depending on what purpose the technology is used for. $R\&D$ may be devoted to improving old processes or products in the direction of saving skilled or unskilled labour, or to introducing new processes or products, which may have a higher technological content. Likewise, ICT per se could be skilled labour (i.e. non-production workers) saving if it mainly involves automatisation of simple clerical tasks (see Bresnahan et al., 2000). For this reason distinguishing the $R\&D$ and ICT intensity by destination

Table 11: Change in employment share - with *R&D* by destination and *ICT* by type (OLS)

Variable	Coef.		s.e.
dln(K)	-0.06		0.04
dln(Y)	-0.36	***	0.08
ICT			
hardware	3.18		10.57
software	13.28		12.16
telecommunications	105.67	*	61.71
R&D			
improvement old processes	-26.59	***	6.95
improvement old products	-7.21		4.61
introduction new products	2.51		2.90
introduction new processes	21.72	***	5.32
other	8.80		33.14
constant	0.03		0.04
N. observations	825		
Adjusted R^2	0.07		
Wald test (p-value)	5.94 (0.00)		
White het. test (p-value)	25.8 (1.00)		

Notes: *** significant at 1%, ** significant at 5%, * significant at 10%. P-values are reported in brackets. Supplier Dominated sectors are the reference category. The table reports the Wald test for the joint significance of all regressors (except the constant) and the White test for heteroskedasticity of unspecified form.

and type, respectively, 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 are shown in table 11. In this part of the analysis we used only the first measure of *R&D* and *ICT* intensity (i.e. *R&D*$/Y$ and ICT/Y) since it is most often used in the literature and because our previous estimates show that the results are robust to alternative measures. From table 11 we notice that the *R&D* devoted to improving old processes has a statistically significant (at 1%) negative effect on the skill-ratio while *R&D* spent to introduce new processes has a statistically significant (at 1%) positive effect on the skill-ratio. The latter results are not surprising since new processes are typically more unskilled labour saving and require a skill upgrading of the internal organisation of a firm. This evidence is compatible with Falk (1999), who studying a sample of manufacturing firms in Germany finds that the implementation of new processes and new products has the greatest effect on the employment structure. As to *ICT*, there is a significant (at 10%) positive effect of expenditures on telecommunications on the skill-ratio.

In the lights of the evidence recently reported by Piva and Vivarelli

Table 12: Change in employment stocks - (SUR)

Variable	Non-production workers			Production workers			All workers (OLS)		
	Coef.		s.e.	Coef.		s.e.	Coef.		s.e.
dln(K)	0.01		0.02	0.07	***	0.02	0.04	***	0.01
dln(Y)	0.06		0.04	0.37	***	0.04	0.26	***	0.02
(R&D/Y)	1.14		1.02	-1.36	*	0.81	-0.46		0.55
(ICT/Y)	-1.14		3.13	-3.45		2.49	-1.90		1.71
constant	0.09	***	0.02	0.04	**	0.02	0.05	***	0.01
N. observations	832			832			832		
R^2	0.00			0.14			0.14		
Chi∗2 (regression significance)	3.50 (0.48)			137.05 (0.00)			3.74 (0.00)[a]		
B-P test of independence	25.07 (0.00)						-		

Notes: *** significant at 1%, ** significant at 5%, * significant at 10%. [a]Wald test for the overall significance of the regression (all coefficients but the constant are equal to zero). P-values are reported in brackets. Supplier Dominated sectors are the reference category. The table reports the LR test for the joint significance of all regressors (except the constant) and the Breusch and Pagan test for independence of the two equations. The effect on the stock of non-production and production workers has been simultaneously estimated using the SUR method while the effect on the stock of all workers using the ordinary least squares (OLS).

(2002a,b) of the central role of organizational change in the explanation of the skill bias for Italy and as a robustness check, we re-estimated all the above regressions including a dummy for the introduction of organizational changes in the period 1995-1997. In none of the estimated regressions the dummy turned out to be statistically significant at conventional levels. The difference with Piva and Vivarelli's (2002b) results may be due to the different specification that we adopted, since we used measures of R&D intensity rather than a dummy for R&D investment,[34], included ICT intensity, which may be highly correlated with organizational changes, and considered a different time period.[35]

6.2 Changes in stocks of non-production and production workers

In this section we describe the results of the estimation of the dynamics in the employment stocks by type of worker, non production and production, respectively. The dependent variables are $\Delta_3 l_{it}^{WC}$ and $\Delta_3 l_{it}^{NC}$, where $\Delta_3 l_{it}^{WC} = ln(L_{it}^{WC}) - ln(L_{it-3}^{WC})$, $\Delta l_{it}^{BC} = ln(L_{it}^{BC}) - ln(L_{it-1}^{BC})$, and L_t^{WC} and L_t^{BC} are the stocks of non-production and production workers, respectively. In words, our dependent variables are the rates of change of the stocks of non-production

[34]Which was used by Piva and Vivarelli (2002a,b) since R&D expenditure was not provided by early waves of the SIM.

[35]Moreover, Piva and Vivarelli (2002a,b) selected data on firms simultaneously appearing in three waves (i.e. 1989-1991, 1992-1994 and 1995-1997), fact which may have introduced a sample selection bias in their analysis.

Table 13: Change in employment stocks - with Pavitt sectors interaction terms (SUR)

Variable	Non-production workers			Production workers			All workers (OLS)		
	Coef.		s.e.	Coef.		s.e.	Coef.		s.e.
dln(K)	0.02		0.02	0.06	***	0.02	0.05	***	0.01
dln(Y)	0.08	*	0.04	0.36	***	0.04	0.26	***	0.02
(R&D/Y)	2.15		1.81	-6.31	***	1.44	-2.11	**	1.00
(R&D/Y)*Scale I.	0.06		3.73	9.90	***	2.97	2.48		2.07
(R&D/Y)*Specialized S.	-2.64		2.26	6.97	***	1.80	2.24	*	1.26
(R&D/Y)*Science B.	10.64		6.85	1.06		5.46	4.12		3.81
(ICT/Y)	-6.40		5.76	-0.28		4.59	-1.23		3.20
(ICT/Y)*Scale I.	6.16		9.06	-10.16		7.22	-3.26		5.03
(ICT/Y)*Specialized S.	3.66		7.25	-1.49		5.78	-0.73		4.03
(ICT/Y)*Science B.	70.65	***	20.85	-21.52		16.61	4.67		11.58
Scale Intensive	-0.03		0.05	0.04		0.04	0.01		0.03
Specialized Suppliers	-0.01		0.04	-0.01		0.03	-0.01		0.02
Science Based	-0.35	***	0.12	0.14		0.09	-0.02		0.07
constant	0.10	***	0.03	0.03		0.02	0.06	***	0.01
N. observations	832			832			832		
R^2	0.04			0.17			0.15		
Chi^2 (regression significance)	33.19 (0.00)			168.04 (0.00)			11.12 (0.00)[a]		
B-P test of independence	21.85 (0.00)						-		

Notes: *** significant at 1%, ** significant at 5%, * significant at 10%. [a]Wald test for the overall significance of the regression (all coefficients but the constant are equal to zero). P-values are reported in brackets. Supplier Dominated sectors are the reference category. The table reports the LR test for the joint significance of all regressors (except the constant) and the Breusch and Pagan test for independence of the two equations. The effect on the stock of non-production and production workers has been simultaneously estimated using the SUR method while the effect on the stock of all workers using the ordinary least squares (OLS).

and production workers, respectively. Our independent variables are the same as we used in the previous section. The change in stocks for the two components of the employment share were estimated simultaneously using Zellner's Seemingly Unrelated Regression (SUR) on the system of equations 3, which unlike separate OLS estimation of the two equations, does not rely on the independence assumption between the error terms of the two equations (which can be tested within the SUR framework).

Table 12 reports the results of the simplest specification. It is possible to note the very low proportion of the variation in the rate of change of the skilled labour stock explained by the regressors. A Likelihood Ratio (LR) test for the joint exclusion of all regressors but the constant term cannot be rejected. Things are slightly better for production workers, where capital and turnover are statistically significant at 1%, with a *ceteris paribus* elasticity of 0.07 and 0.37, respectively. $R\&D$ is only marginally significant (at the 10% level) and has a negative impact on the growth rate of non-production workers. The Breusch and Pagan test for independence of the two equations (see Breusch and Pagan 1980) is strongly rejected, SUR is therefore efficient. We also reported in Table 12 the effect of the same regressors included in the simultaneous equation model on the stock of total employment estimated with OLS. Both capital stock and turnover have a statistically significant positive impact on total employment, the elasticities are 0.04 and 0.26, respectively, while the effect of technological variables is negative although not statistically significant.

By interacting the $R\&D/Y$ and ICT/Y with Pavitt sectors we find other interesting results, which are shown in table 13.

For non-production workers the R^2 rises to 4%. Now turnover is statistically significant at 10%, the *ceteris paribus* elasticity of Δl_{it}^{WC} with respect to Y is 0.08. The main results concern firms in the Science Based sectors. Looking at the sectoral dummy it is possible to notice a common negative sectoral effect on white collars' growth: this result is in contrast with the positive growth rate registered in the sample descriptive statistics, which is the highest among Pavitt sectors (see table 7). However, this apparent contradiction disappears if we look at the interaction term between Science Based sectors and ICT intensity, which is significant at the 1% level. This effect is positive and big enough to counteract the common sectoral effect: increasing by one percent point the ratio raises Δl_{it}^{WC} by about 7%. Another problematic evidence is that the R&D effect in Science Based sectors although positive is not significant; in fact, is in this sector where the impact of R&D on the skill upgrading should be particularly strong. These two facts, the positive impact of ICT intensity and the not significant effect of R&D intensity offer a coherent interpretation of the Italian Science Based sectors. First of all, in these sectors a high ICT intensity represents a necessary condition to undertake production, while R&D activities are necessary to remain innovative. As reviewed in the previous sections, Italy experienced a despecialisation and

Table 14: Change in employment stocks - with *R&D* by destination and *ICT* by type (SUR)

Variable	Non-production workers			Production workers			All workers (OLS)		
	Coef.		s.e.	Coef.		s.e.	Coef.		s.e.
dln(K)	0.01		0.02	0.06	***	0.02	0.04	***	0.01
dln(Y)	0.05		0.04	0.37	***	0.04	0.26	***	0.02
ICT									
hardware	-1.14		6.01	-2.34		4.75	-1.37		3.31
software	1.45		6.91	-8.33		5.46	-4.06		3.81
telecommunications	-33.18		35.08	24.33		27.71	19.09		19.34
R&D									
improvement old processes	-0.86		3.95	8.22	***	3.12	1.32		2.18
improvement old products	-1.77		2.62	2.26		2.07	-0.04		1.45
introduction new products	2.15		1.65	-1.48		1.30	0.04		0.91
introduction new processes	3.90		3.03	-10.37	***	2.39	-3.12	*	1.67
other	-15.63		18.84	-16.71		14.88	-15.09		10.39
constant	0.09	***	0.02	0.03	**	0.02			
N. observations	825			825			825		
R^2	0.01			0.17			0.1503		
Chi∗2 (regression significance)	7.63 (0.66)			168.99 (0.00)			14.40 (0.00)[a]		
B-P test of independence	21.22 (0.00)						-		

Notes: *** significant at 1%, ** significant at 5%, * significant at 10%. [a]Wald test for the overall significance of the regression (all coefficients but the constant are equal to zero). P-values are reported in brackets. Supplier Dominated sectors are the reference category. The table reports the LR test for the joint significance of all regressors (except the constant) and the Breusch and Pagan test for independence of the two equations. The effect on the stock of non-production and production workers has been simultaneously estimated using the SUR method while the effect on the stock of all workers using the ordinary least squares (OLS).

decline of Science Based sectors: as a consequence most Science Based firms operate simply as subcontractors or as units of production of multinational groups which carry out the research activity abroad.

By including interaction terms also the R^2 of the production workers equation increases, to 17%. The estimates of the effect of capital and turnover change only marginally with respect to those given in table 12. However, a heterogenous effect of *R&D* across Pavitt sectors emerges. While the effect is negative in Supplier Dominated sectors, the impact is positive for Scale Intensive and almost null in Specialized Suppliers sectors. These effects are compatible with those of table 9, where the effects on the skill-ratio for the three sectors above were positive (Supplier dominated), negative (Scale Intensive) and negative (Specialized Suppliers), respectively.

When considering the effect of technological variables on total employment, it is evident from table 13 the overall labour-saving effect of R&D expenditures, only in Specialized Suppliers firms the effect is almost null.

Table 14 reports the estimates for *R&D* and *ICT* by destination and type, respectively. None of the regressors in the non-production workers equation is significant. In the production workers equation the most interesting result is the heterogenous effect of $R\&D$ with respect to its destination. While the $R\&D$ devoted to the improvement of old processes raises the growth rate of production workers, the $R\&D$ for the introduction of new processes exerts a negative impact on the latter. These effects are compatible with those reported in table 11. Table 14 also qualifies the previous result of an overall labour-saving effect of R&D, showing that it is mainly due to R&D devoted to the introduction of new processes which has this effect.

7 Concluding remarks

The aim of this paper was to perform a test for the presence of Skill-Biased Technological Change (SBTC) in the Italian manufacturing industry. The interest of this topic stems from two main motives. The first is that the bulk of the literature finding support for the SBTC hypothesis is focusing on the US and the UK, while studies investigating European countries either find mixed evidence or uncover other explanatory factors for the skill bias (e.g., France). The second is that this research issue is not well covered for Italy. The latter motive is not only important *per se* but also since Italy represents an interesting case study because of its peculiar institutional features (especially in the labour market) and model of specialization. Indeed, Italy has a productive specialization based on traditional industries and 'light' mechanics, and an industrial demography based on small and medium sized firms and industrial districts. As a result, innovative activities have mainly an incremental character and are focused on embodied technical change. This also explains the low intensity of formal R&D expenditures of Italian firms. All these aspects affect firms' labour demand and qualify Italian manufacturing as a poor absorber of highly skilled workers.

Our study is based on firm-level Italian data, on which empirical evidence is particular scarce. We use panel data from the Survey of Italian Manufacturing (by Capitalia) derived from merging two three-year waves (1995-1997, 1998-2000). For this period the Survey gathers detailed information on R&D and ICT expenditures of manufacturing firms, also classified by destination and type, respectively. This represents a noticeable improvement in terms of the possibility of constructing good proxies for technological capital as compared to earlier waves which mainly provided qualitative indicators for the technological variables. In the empirical analysis, we focus on the impact of both R&D and ICT intensities on the skill-ratio (the number of white collars divided by that of blue collars). While the former indicator is traditionally used as a proxy for technological capital, the latter has only recently begun to be available and used in empirical work.

In this paper, we do not only examine the effect of technological variables on the skill-ratio but also on its two components.

First, we investigate the impact of the total amount of R&D and ICT intensities on the skill-ratio. The estimated coefficients of the technological variables turn out not to be significant at conventional statistical levels. We go farther by distinguishing the R&D and ICT indicators by Pavitt sectors and destination and type, respectively. The impact of R&D becomes significant when distinguishing its effect by Pavitt sectors. In particular, our analysis shows that R&D generates 'skill upgrading' in Supplier Dominated sectors only, while the effect on the skill-ratio is negative in Scale Intensive and Specialized Suppliers sectors. We also find evidence of heterogeneity of the effect of R&D according to destination on the skill-ratio: R&D devoted to the improvement of old processes generates a decrease and that devoted to the introduction of new processes an increase of the skill ratio. By contrast, the ICT variables remain not significant even when finer disaggregations either by type or Pavitt sectors are included in the regression.

Second, we analyze the effect of R&D and ICT on the two components of the skill-ratio: white collars and blue collars. We find that R&D intensity affects the stock of production workers only: skill upgrading or degrading run mainly through the effect on the denominator of the skill-ratio, i.e. through hiring or firing of new production workers. When considering the aggregate measure of R&D the effect on the stock of production workers is negative and statistically significant at the 10% level. Our analysis also shows the heterogeneity of the effect of R&D on the stock of blue collars according to Pavitt sectors: the effect is positive for Scale Intensive and Specialized Suppliers sectors and negative in Supplier Dominated and Science Based sectors, and always significant at the 1% statistical level. As far as the destination of R&D and its impact on the stock of production workers are concerned, R&D carried out to improve old processes has a positive effect while that devoted to introducing new processes has a negative one. It is important to stress that these two findings are closely related and can be seen as the two faces of the same coin. Indeed, from the previous literature on innovation (see section 3.1) we have already seen that traditional (i.e. Supplier Dominated) sectors are mainly focused on process innovations and incremental product innovations while Specialized Suppliers invest mainly in incremental product innovations. Coherently with these findings, our analysis characterize the implications in terms of skill bias of these innovative behaviours. First, for traditional sectors the overall impact on production workers of a more intense innovative behaviour is substantially negative and significant. Second, for Specialized Suppliers and Scale Intensive sectors the effect of innovative behaviour is positive meaning that the labour-saving impact is more than compensated by the competitiveness-enhancing effect.

By contrast, in general we find no significant effect on non-production workers. A noticeable exception is that of ICT expenditures in Science Based industries whose effect is positive, statistically significant and of remarkable magnitude. This fact can be interpreted in the light of the overall situation of the Italian Science Based sector and the pervasive nature of ICT expenditure, particularly evident in the sectors with the highest technological opportunities.

To conclude, our analysis points to the fact that the skill biased technological change in the manufacturing industry can assume different forms according to the specialization and pattern of development of a country. In Italy, for instance, we mainly find a significant impact of technological capital on production workers only.

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Appendix

In this Appendix we report the results of the regressions with interaction terms between Pavitt sectors and R&D by destination and ICT by type. We do not emphasise these results since due to the very low number of innovative firms, interacting Pavitt sectors with R&D by destination and ICT by type causes problems of small cells size, and the generalisibility of the results is dubious. However, we report the estimates for the sake of completeness.

Table 15 reports the results of the specification of the employment share equation including interaction terms between R&D by destination and ICT by type and Pavitt sectors. The analysis reveals that the bulk of the positive effect of ICT on the skill-ratio is in Scale Intensive Sectors. The positive effect of $R\&D$ devoted to the introduction of new processes is general and homogeneous across Pavitt sectors. $R\&D$ devoted to the introduction of new products has a negative effect on the skill-ratio in Scale Intensive sectors, while it has a positive effect in Science Based sectors.

Finally, tables 16-17 report the results of the specification of the WC and BC equations including interaction terms between $R\&D$ by destination, ICT by type and Pavitt sectors. From table 16, while ICT on telecommunications in the Specialized Suppliers sectors, $R\&D$ for old products in Scale Intensive sectors, $R\&D$ for new products in Science Bases sectors and $R\&D$ for new processes in all but the Scale Intensive sectors all have a positive effect on the growth rate of non-production workers, the effect of $R\&D$ for new processes in scale intensive sectors is negative. From table 17, the effect of ICT expenditures for hardware have a negative impact in the growth rate of production workers in scale intensive sectors, the effect of $R\&D$ for new processes has a negative impact on the dependent variable in all Pavitt sectors, while that of R&D for old processes is positive and significant only in Scale Intensive sectors.

Table 15: Change in employment share - with *R&D* by destination and *ICT* by type and Pavitt sectors interaction terms (OLS)

Variable	Coef.		s.e.	Variable	Coef.		s.e.
dln(K)	-0.06		0.04	(cont'd)			
dln(Y)	-0.32	***	0.08				
(ICT hardware/Y)	-13.23		27.47	(R&D old products/Y)	-2.84		15.52
(ICT hardware/Y)*Scale I.	37.54		40.21	(R&D old products/Y)*Scale I.	38.13		45.34
(ICT hardware/Y)*Specialized S.	11.29		30.65	(R&D old products/Y)*Specialized S.	0.34		16.59
(ICT hardware/Y)*Science B.	106.81		183.28	(R&D old products/Y)* Science B.	-2.59		27.27
(ICT sofware/Y)	15.54		29.24	(R&D new products/Y)	8.08		5.43
(ICT sofware/Y)*Scale I.	-10.24		34.25	(R&D newproducts/Y)*Scale I.	-55.69	***	19.43
(ICT sofware/Y)*Specialized S.	-4.52		36.53	(R&D new products/Y)*Specialized S.	-11.56	*	6.61
(ICT sofware/Y)*Science B.	-147.73		242.14	(R&D new products/Y)* Science B.	42.10	**	20.99
(ICT telecom./Y)	-19.34		100.47	(R&D new processes/Y)	26.14	***	7.31
(ICT telecom./Y)*Scale I.	455.70	***	156.85	(R&D new processes/Y)*Scale I.	-8.75		18.69
(ICT telecom./Y)*Specialized S.	45.46		146.31	(R&D new processes/Y)*Specialized S.	-18.42		12.51
(ICT telecom./Y)*Science B.	-710.57		518.21	(R&D new processes/Y)* Science B.	-25.61		57.21
(R&D old processes/Y)	-1.75		22.33	(R&D other/Y)	-22.41		51.81
(R&D old processes/Y)*Scale I.	-40.20		24.86	(R&D other/Y)*Scale I.	93.07		126.16
(R&D old processes/Y)*Specialized S.	-14.26		24.87	(R&D other/Y)*Specialized S.	33.83		68.84
(R&D old processes/Y)* Science B.	10.60		42.11	(R&D other/Y)* Science B.	-		-
				Scale Intensive	-0.08		0.08
				Specialized Suppliers	0.03		0.07
				Science Based	0.06		0.25
				constant	0.04		0.05
N. observations				825			
Adjusted R^2				0.09			
Wald test (p-value)				3.17 (0.00)			
White het. test (p-value)				51.75 (0.00)			

Notes: *** significant at 1%, ** significant at 5%, * significant at 10%. P-values are reported in brackets. Supplier Dominated sector is the reference category. The table reports the Wald test for the joint significance of all regressors (except the constant) and the White test for heteroskedasticity of unspecified form.

Table 16: Change in employment stocks - with *R&D* by destination and *ICT* by type and Pavitt sectors interaction terms (SUR): Non-production workers

Variable	Non-production workers						
	Coef.		s.e.	Variable	Coef.		s.e.
dln(K)	0.00		0.02	(cont'd)			
dln(Y)	0.11	***	0.04				
(ICT hardware/Y)	-14.96		15.37	(R&D old products/Y)	6.45		8.68
(ICT hardware/Y)*Scale I.	33.55		22.50	(R&D old products/Y)*Scale I.	51.67	**	25.37
(ICT hardware/Y)*Specialized S.	11.43		17.15	(R&D old products/Y)*Specialized S.	-8.97		9.28
(ICT hardware/Y)*Science B.	64.60		102.57	(R&D old products/Y)* Science B.	-16.15		15.26
(ICT sofware/Y)	7.06		16.36	(R&D new products/Y)	-1.08		3.04
(ICT sofware/Y)*Scale I.	-16.02		19.17	(R&D newproducts/Y)*Scale I.	-12.19		10.87
(ICT sofware/Y)*Specialized S.	-9.30		20.44	(R&D new products/Y)*Specialized S.	0.63		3.70
(ICT sofware/Y)*Science B.	23.14		135.51	(R&D new products/Y)* Science B.	29.29	***	11.75
(ICT telecom./Y)	-91.51		56.22	(R&D new processes/Y)	6.89	*	4.09
(ICT telecom./Y)*Scale I.	87.68		87.78	(R&D new processes/Y)*Scale I.	-20.61	**	10.46
(ICT telecom./Y)*Specialized S.	155.17	*	81.88	(R&D new processes/Y)*Specialized S.	-3.10		7.00
(ICT telecom./Y)*Science B.	-169.88		290.01	(R&D new processes/Y)* Science B.	-29.11		32.02
(R&D old processes/Y)	-5.78		12.50	(R&D other/Y)	-35.88		29.00
(R&D old processes/Y)*Scale I.	9.90		13.91	(R&D other/Y)*Scale I.	-24.52		70.60
(R&D old processes/Y)*Specialized S.	1.06		13.92	(R&D other/Y)*Specialized S.	39.20		38.52
(R&D old processes/Y)* Science B.	9.02		23.57	(R&D other/Y)* Science B.	-		-
				Scale Intensive	-0.06		0.05
				Specialized Suppliers	-0.01		0.04
				Science Based	-0.13		0.14
				constant	0.10	***	0.03
N. observations	825						
R^2	0.07						
LR test (regression significance)	62.5 (0.00)						
B-P test of independence	17.83 (0.00)						

Notes: *** significant at 1%, ** significant at 5%, * significant at 10%. P-values are reported in brackets. Supplier Dominated sectors are the reference category. The table reports the LR test for the joint significance of all regressors (except the constant) and the Breusch and Pagan test for independence of the two equations.

Table 17: Change in employment stocks - with *R&D* by destination and *ICT* by type and Pavitt sectors interaction terms (SUR): Production workers

Variable	Production workers						
	Coef.		s.e.	Variable	Coef.		s.e.
dln(K)	0.06	***	0.02	(cont'd)			
dln(Y)	0.37	***	0.04				
(ICT hardware/Y)	12.29		12.28	(R&D old products/Y)	-3.75		6.94
(ICT hardware/Y)*Scale I.	-33.18	*	17.98	(R&D old products/Y)*Scale I.	-8.55		20.27
(ICT hardware/Y)*Specialized S.	-12.37		13.70	(R&D old products/Y)*Specialized S.	4.78		7.42
(ICT hardware/Y)*Science B.	-51.74		81.94	(R&D old products/Y)* Science B.	4.87		12.19
(ICT sofware/Y)	-11.92		13.07	(R&D new products/Y)	-3.14		2.43
(ICT sofware/Y)*Scale I.	8.88		15.31	(R&D newproducts/Y)*Scale I.	7.63		8.69
(ICT sofware/Y)*Specialized S.	0.75		16.33	(R&D new products/Y)*Specialized S.	4.34		2.96
(ICT sofware/Y)*Science B.	25.73		108.26	(R&D new products/Y)* Science B.	-6.83		9.38
(ICT telecom./Y)	11.62		44.92	(R&D new processes/Y)	-12.47	***	3.27
(ICT telecom./Y)*Scale I.	-11.29		70.13	(R&D new processes/Y)*Scale I.	2.62		8.36
(ICT telecom./Y)*Specialized S.	34.60		65.42	(R&D new processes/Y)*Specialized S.	7.81		5.60
(ICT telecom./Y)*Science B.	353.08		231.69	(R&D new processes/Y)* Science B.	14.90		25.58
(R&D old processes/Y)	-8.75		9.98	(R&D other/Y)	-1.33		23.17
(R&D old processes/Y)*Scale I.	26.63	***	11.11	(R&D other/Y)*Scale I.	-79.81		56.41
(R&D old processes/Y)*Specialized S.	13.34		11.12	(R&D other/Y)*Specialized S.	-16.79		30.78
(R&D old processes/Y)* Science B.	2.50		18.83	(R&D other/Y)* Science B.	-		-
				Scale Intensive	0.05		0.04
				Specialized Technology	-0.01		0.03
				Science Based	0.04		0.11
				constant	0.03		0.02
N. observations	825						
R^2	0.20						
LR test (regression significance)	210.37 (0.00)						
B-P test of independence	17.83 (0.00)						

Notes: *** significant at 1%, ** significant at 5%, * significant at 10%. P-values are reported in brackets. Supplier Dominated sectors are the reference category. The table reports the LR test for the joint significance of all regressors (except the constant) and the Breusch and Pagan test for independence of the two equations.