Skill-Biased Technological and Organizational Changes:

Empirical Evidence for Two Italian Local Production Systems.

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Abstract

The analysis of the workforce composition dynamic has been a hot issue in the economic field for many years. The shifting of labour demand towards relatively more skilled workers has been interpreted in several ways. A consolidated explanation is that technological change has driven the labour demand with detrimental consequences for less skilled workers (*skill-biased technological change*). More recently the role of organizational change has been investigated as well (*skill-biased organisational change*).

The main objective of the present work is to verify the interactions between technological change, organizational change and the workforce composition within an integrated framework that also leads us to consider the role of specific aspects of the industrial relations system.

The empirical analysis is based on original datasets which include data on manufacturing firms for two Italian local production systems, located in the Emilia-Romagna region: Modena and Reggio Emilia. The results show the existence of a relation between specific aspects of technological and organizational changes and the workforce composition in terms of white collars and blue collars workers.

In particular, the upskilling effect is mainly associated with technological change, while organisational change is more linked to a detrimental effect on less skilled workers. The existence of complementarities seems to be supported by the results associated with interaction terms between technological and organisational variables. Finally, the industrial relations variables provide mixed results indicating non univocal results between good quality industrial relations and workforce composition.

JEL Classification: J24, J53, L23, L6, O33

Keywords: local production systems, technological change, organizational change, industrial relations, skills

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Introduction

During the last decades western developed economies have experienced increasing inequalities within the labour market. The sharp increase in wage inequality, especially in Anglo-Saxon countries, between skilled and unskilled workers has been considered as a result of the rapid spread of new technologies. The wage effect of technological change is just one side of the inequality phenomenon; the other one concerns the labour demand. The shifting of labour demand in favour of better-educated/skilled workers, with a detrimental effect for less-educated/unskilled workers, appears to be soundly verified in several empirical studies. However, the relation between human skills and technological change, not least the phenomenon of computerization, is not trivial as it can seem: we may question for example whether technological change complements the high skilled workforce performance or if it acts as a substitute for less skilled workers or both. In addition, technological change may efficaciously complements some high skilled workers performances but not others, or it may substitute for some less skilled activities but not for others [Autor *et al.*, 2001].

More recently, another stream of literature has provided further explanations about the skill bias phenomenon [Lindbeck and Snower, 1997]. It is argued that recent trends in organizational change, involving decentralisation, reduction of hierarchical levels and introduction of high performance work practices, are potential factors explaining the increasing demand for skilled workers. The amount of empirical evidence on this issue remains very far away from that concerning the relation between technology and skills.

Finally, a third bunch of works [Cappelli, 1996; Caroli and Van Reenen, 2001; Bresnahan *et al.*, 2002] take into consideration the complementarities existing between technological change, organisational change and skills. A general result seems to confirm the existence of complementarities, although both technological and organisational changes may have independent effects on workforce composition.

Because the works adopting an integrated view on the issues briefly sketched above are still scanty, the present paper aims to provide further evidence regarding the relations between technological change, organisational change and workforce composition at firm level. An additional valued added of the paper consists in considering also industrial relations characteristics, to be intended as cooperative employment relationships at firm level acting as components of new organizational forms, as potential influencing factors of the occupational composition.

The paper is organized as follows. Section 1 presents a review of both theoretical literature and empirical evidence regarding the skill biased technological and organisational changes. Section 2 outlines the empirical model and in section 3 the main results of the empirical investigation are discussed. Section 4 is left to concluding remarks.

1. Related literature

1.1 Theoretical approaches

During the last thirty years the principal OECD countries have experienced significant changes in the functioning of labour market and an increasing inequality between different types of workers [Acemoglu, 2002]. In particular, relative wages and the number of qualified (skilled) workers seem to be constantly risen [Autor *et al.*, 1998; OECD, 1996]; in the same period the number of under-qualified (unskilled) workers has strongly decreased [OECD, 2001]. By country these changes have been very heterogeneous according to different institutional characteristics of national labour markets. It appears that in Anglo-Saxon countries, characterized by more flexible labour markets, the decrease in the demand for unskilled workers has led to increasing wage differentials between skilled and unskilled workers (wage effect). On the contrary, in countries with less flexible labour markets, the change in demand has conducted to rising unemployment for unskilled workers (occupational effect) [OECD, 1996]. Not by chance some authors notice in the unemployment rise in Europe the flip side of the rise of earnings inequality in the US [Freeman, 1995].

Thus, what is the mechanism that led to this evidence?

During the last decades we have assisted to a strong increase in the supply of college skills. In 1939 just over 6% of US workers were college graduates; in the 1996 this percentage rose to over 28% [Acemoglu, 2002]. This event concerned not only the American economy but also European countries[1]. Economic theory suggests that with such an increase in the supply of skills, real wages of the skilled workers should be decreasing; nevertheless what happened was exactly the opposite. In order to justify this increase in earnings, the only explanation can be found on the demand side of the market, that augmented more with respect to the increase in the supply.

Hence, the right question should be: what is the reason of this increase in the demand for skilled labour?

The consolidated answer calls for technological change and the potential bias it may induce on labour demand. Many authors see a causal relationship between technological change and the radical shift in the occupational structure [Berman *et al.*, 1994; Sanders and ter Weel, 2000; Autor *et al.*, 2001]. In the last forty years, in fact, there has been an exponential production and diffusion of modern technologies; many progress, particularly, have involved Information and Communication Technologies (ICTs). The rapid and continuing decline in the cost of computing

[1] In Italy, for example, the average number of years of education has tripled during sixties years: it passed from 4.5 at the beginning of the past century to 11.5 with the baby-boom generation [Checchi, 2001].

and the expansion in the variety of computer systems are important changes in the environment around the firms and they have also led to strong investments in technological innovations [Bresnahan *et al.*, 2000].

The importance of technological innovations for growth has been recognised since the development of classical economic theory by Adam Smith and David Ricardo. In the modern growth theory, many authors have tried to examine technological innovation as endogenous factor [Romer, 1986; Lucas, 1988; Romer, 1990], reconsidering the works of those classical economists and going beyond the concept of the firm with a black-box technology. More recent approaches, mainly the economics of innovation along the evolutionary theory of the firm which considers technology not as a simple information, but as a multidimensional element closely related to skills [Nelson and Winter, 1982; Freeman, 1982; Dosi, 1988], were crucial in developing new theoretical instruments which have changed the focal point of economic studies regarding the relationship between technology and labour force. In fact until the Nineties the studies focused prevalently on the quantitative effects of technological change on workforce, considered as group of individuals with same features. Nevertheless during the last twenty years, the attention toward tasks and skills of the workers in production activities has strongly increased, shifting from a *quantitative* analysis of the labour market to a *qualitative* one, to capture and explain changes in the relative demand for labour. Nowadays, as a result, the main theories assert that there is a clear complementary relationship between modern technological innovations and skilled workforce [Acemoglu, 2002]. Hence, the principal explanation of the strong increase in the demand for skilled workers occurred during the last decades is the theory of "Skill-Biased Technological Change" (SBTC).

The SBTC is not the only explanation of the recent up-skilling of the workforce. Another hypothesis, not necessarily opposite to the first and suggested more recently, is rooted in the evolutionary theory of the firm. This second stream of literature is based on the idea that the increasing diffusion of new organizational structures and new work organizational practices is an important explanation of the increase in the demand for skilled workers [Lindbeck and Snower, 1996; Caroli and Van Reenen, 2001]. Actually, the changes occurred in the firms organisational structure in the last decades have directly impacted on the human capital of the firms. These latter are now more oriented toward de-specialized workers with multidimensional capabilities which minimize the routine of the tasks: new organizational practices have increased the demand for qualified human capital and risen emphasis on the "intellectual skills". The theory of the "Skill-Biased Organizational Change" (SBOC) asserts that decentralization, delayering, team work, multi-tasking and all what is generally called *High Performance Work Practices (HPWP)* necessitate of more responsible and autonomous workers, with higher skills [2].

In addition, some authors consider technological and organizational explanations together: in order to introduce important and expensive new technologies, embodied in new machinery or computers, firms cannot disregard significant changes within the organizational structure[3] [Aghion *et al.*, 1999; Bresnahan, 1999; Caroli, 2001]. So, if firms wish to introduce important technological innovations to achieve superior performance, they should modify their organization giving to the workers more autonomy and responsibility and clearly this is only possible when firms have skilled workers, capable to accomplish these changes. This joint vision calls attention to the role of complementarities between different decision variables within the firm, what Milgrom and Roberts (1990) called “super-additive effects”. In addition, following Nelson (1995), it appears very important the approach by Loasby (1998a, 1998b), which is consistent with the idea that the learning process is not an idiosyncratic experience and that a firm is like an organization where the body of knowledge (know-how) goes beyond the simple addition of its different single parts.

1.2 Empirical evidences

A large number of studies concerning the relationship between introduction of technological innovations and workforce composition (SBTC) emerged in the Nineties to explan the rapid increase of skilled workers in US and UK. This issue has been extensively analysed in empirical economic literature employing sector-level [Berman *et al.*, 1994; Autor *et al.*, 1998; Betts, 1997; Goux and Maurin, 2000; Morrison Paul and Siegel, 2001] or firm-level data [Casavola *et al.*, 1996; Dunne *et al.*, 1996; Doms *et al.*, 1997; Aguirregabiria *et al.*, 2001; Mairesse *et al.*, 2001].

The fundamental proposition of the industry-level analyses is that SBTC is an event that affects the relative productivity of the different skill groups[4] at the same rate in all sectors of the economy [Antonietti, 2007]. For the US manufacturing sector Bartel and Lichtenberg (1987), Berman *et al.* (1994), Autor *et al.* (1998) and Morrison Paul and Siegel (2001) find a positive and robust

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[2] A vision similar to the endogenous one offered by Acemoglu (1998) for the technological explanation, is presented by Caroli *et al.* (2001) for the organizational explanation. The authors suppose the existence of two organizational models: the first centralized with a clear separation between the phase of the conception and the phase of the execution; the second decentralized, characterized by autonomy and self-responsibility of workers. The basic result is that when in the economy the number of the skilled workers is higher than the number of the unskilled one, the firms provide incentives to reorganize themselves.

[3] Even not considering explicitly the skill bias argument, Pini and Santangelo (2010) presupposed a reverse relationship; therefore different types of organization and workers’ competence have different impacts on the introduction of different types of innovations, radical and incremental.

[4] In the literature, especially empirical, the workers’ skills are usually measured by tasks: skilled are non-manual workers (or White Collar workers), while unskilled are manual workers (or Blue Collar workers). Another measure, less precise, consider the educational qualification [Berman *et al.*, 1994 and Machin, 1996].

relationship between technology (measured normally by computer usage and R&D investments, but sometimes by the mean age of capital stock) and the demand for skilled (high educated) workers. In addition, the same works show an opposite relationship between technology and unskilled (low educated) workers. Instead, the work by Goux and Maurin (2000) for France does not fully confirm the SBTC hypothesis; it appears in fact that the spread of computers and new production technologies do not particularly contribute to the replacement of skilled with unskilled labour. Other US studies regarding the introduction of advanced computer-based machine use firm-level data sets. Dunne *et al.* (1996), employing manufactures data (1972-1988), find positive but not significant relationship between advanced computer-based machine and skilled labour; alternatively they verify that the previous relationship is positive and also significant when R&D investment is used as innovative variable. Differently from Dunne *et al.* (1996), Adams (1999) considers only chemical firms: estimating a SUR model, he finds that firm R&D and investment in equipment are consistently skill biased, while investment in infrastructures are unskill biased. More recently, Dunne and Troske (2004), using information on the use and adoption of seven different information technologies, reveal that the relation differs across various types of technologies: technologies associated with engineering and design task are strongly skill biased; on the contrary technologies associated with production phases are not. Moreover, the work by Machin (1996) for the UK employs not only industry-level but also firm-level data: for the last Eighties the author finds a positive relation between computer (measured by a dummy variable) and skilled workers. Haskel and Heden (1999) confirm this correlation and, in addition, find that computerisations reduces the demand of blue collar workers.

Empirical results concerning “continental” European countries are not robust as those concerning the Anglo-Saxon countries. Employing a cross-section in long differences analysis for the 1986-1994 period and using five ICT and R&D indicators for four work categories, Mairesse *et al.* (2001) underline that for French firms the SBTC phenomenon is not present; nevertheless it is evident a negative correlation between ICT indicators and blue collars workers (only for manufacturing sector). Aguirregabiria and Alonso-Borrego (2001) utilize dynamic panel for Spanish firms (1986-1991) and find that technological capital is skill biased, while physical capital and R&D investments are not. Even stronger are the results by Spitz (2005), which verify powerful complementarities between the use of computer and skilled workers. An innovative element of this last study is the distinction of labour in five categories following the tasks of the workers (non-routine analytical, non-routine interactive, routine cognitive, routine manual and non-routing manual). Lastly, when we come to the Italian context we find the following bunch of studies. Casavola *et al.* (1996) demonstrate that wage dispersion does not increase in Italy by the same extent as in the Anglo-Saxon countries[5], furthermore technological progress lead to a significant increase in the employment of white collars[6]. As Bratti and Matteucci (2004) put in evidence the SBTC in the manufacturing industry can assume different forms according to the specialization and pattern of development of a country. In Italy, for instance, the authors find that from 1995 to 2000 only the R&D expenditures (and not the ICT variable) have negative and significant impact on unskilled (production) workers[7]. Finally, a recent work by Baccini and Cioni (2005) on the Italian textile district of Prato (an Italian province in Toscana), compares current occupation and occupation during the early Eighties. The comparison reveals that technological innovation, in particular changes introduced with ICT, is not necessarily skill biased. It appears, in fact, that technology spreads at different speeds: some of it biased in favour of skilled labour, some are neutral and some biased in favour of unskilled labour.

Given that the technological explanation is not always satisfying (especially for European "continental" countries), several economic and also managerial scholars have recently pointed to another explanation. The principal one concerns the impact of organizational changes on workforce composition (SBOC). Studies concerning such a linkage are certainly few, but they are increasing both in terms of number and in terms of significance [Caroli *et al.*, 2001; Caroli and Van Reenen, 2001; Piva *et al.*, 2005; Bauer and Bender, 2004; Falk, 2001]. Studies regarding the SBOC theory use firm-level data because of the nature of information about the organizational mechanisms, which is available at firm-level, but not at more aggregated ones such as sector-level[8].

The first important empirical study is by Osterman (1994). The author shows that in 1992 above 35% of the 694 US establishments taken into consideration implemented High Performance Work Practices (HPWP), which are correlated with firms that use a technology requiring high level of skills[9]. On the contrary, as shown by Caroli *et al.* (2001) for French manufacturing (1989-1992), it appears that OC has a negative impact on unskilled workers rather than a positive impact on the skilled ones. Caroli and Van Reenen (2001) offer a significant analysis because they compare two panels for French and British firms; the results confirm the SBOC hypothesis, notwithstanding the different social and institutional countries features. For Germany, the works by Falk (2001) and Bauer and Bender (2004) investigate the beginning of Nineties: employing dummy variable as

[5] Probably both the shift in the supply of skills and the features of the Italian wage bargaining system counteracted the rise in earnings dispersion [Casavola *et al.*, 1996].

[6] However, as underlined by Piva (2004), the use of "intangible assets" (directly derived from the balance sheet) as a measure of technological change is partly inadequate because it includes not only R&D investment and patents but also the firm's starting value and the marketing and advertising cost.

[7] Maybe this result is due to the specific traditional Italian sectors, composed prevalently by small and medium enterprises and where the formalized innovative activity is not intense and has low capacity to absorb qualified workers [Bratti and Matteucci, 2004].

[8] Organizational variables are very difficult to obtain [Vickery and Wurzburg, 1998].

[9] In a more recent work, Osterman (2000) supports his previous hypothesis and shows that High Performance Work Practices (HPWPs) continued to diffuse at a rapid rate between 1992 and 1997.

measure of OC, these works provide different results: the former, in fact, suggests that OC has positive effects for all skilled groups, but not for unskilled labour, while the latter points out that OC is skill biased because it reduces predominantly net employment growth rates for unskilled and medium-skilled workers. Finally, for Italy, two important empirical studies provide evidence of the SBOC during the Nineties. Piva *et al.* (2005), estimating a SUR model with over 400 manufacturing firms, show not just that OC is more important than R&D expenditures on the skill structure (it affects negatively the blue collars workers), but also that OC and R&D together have a super-additive effect on skill composition. Furthermore Piva *et al.* (2006), adopting a dynamic panel data analysis for a sample of 22 of the largest machinery firms, emphasize a positive link between OC and skilled workers and confirm some evidence of super-additive effects.

2. Econometric analysis

2.1 Research questions

Changes in the organization of the firm as well as introduction of new technologies, meant both machineries and ICTs, have been recognized to be explanatory factors of the different skill/unskill ratios showed by firms. In this perspective, established literature has argued for distinct impacts of technological and organizational change on firm occupational structure. Our economic hypothesis is a complementary relationship at the firm level between skilled labour demand and several types of innovations. As discussed above, the utilization of an high number of skilled workers is a necessary step for firms which try to increase their performance through R&D expenditures [Dunne *et al.*, 1996], advanced computer-based machine or computer [Doms *et al.*, 1997] or through new organizational practices which led to decentralisation and delayering [Bresnahan *et al.*, 2002], collective work [Osterman, 1994] and multi-tasking activities [Ichniowski and Shaw, 2003]. Therefore, innovations are profitable for firms if they can count on high competences and capabilities of the workers. Therefore, the literature analyzed suggests us the following main research questions:

1. Are input and output factors of technological innovation process or ICT significant explanatory variables of the occupational composition? Does the evidence supports the SBTC hypothesis?

2. Are organizational change or training activities[10] significant explanatory variables of the occupational composition? Does the evidence supports the SBOC hypothesis?
3. Have the different kinds of innovation a super-additive relationship with occupational composition?

In addition we are able to analyze a further linkage between workforce composition and firm level characteristics. The importance of this piece of analysis, which represents an additional value added of the paper, is suggested by a specific, idiosyncratic characteristic of the two local production systems here analyzed (see 2.2 that follows): the deep-rooted unionism. Hence, the additional research question assumes the following form:

4. Are there some linkages between cooperative aspects of the firm industrial relations system and the occupational composition?

2.2 Data and Methodology

Our empirical analysis is conducted on manufacturing firms located in two central provinces of the Emilia-Romagna region in Italy, Modena (MO) and Reggio Emilia (RE).

RE and MO are two provinces characterized by particular LPS (Local Production Systems), with typical features of the Emilia-Romagna regional model: dominant presence of small and medium enterprises (SME), strongly specialized in the chemicals, machinery, food, textile and clothing, and non-metallic minerals sectors [Pini, 2004; Seravalli, 2001]. The prevalence of SME is partially due to the existence of specific districts within the industrial system borders: non-electrical machinery and equipment – especially machinery for mechanical energy and agriculture; non metallic mineral products – especially ceramic tiles; food industry; textile and clothing; biomedical.

The overall characteristics of the industrial context outlined above lead to consider the two LPS as paradigmatic versions of the so called "Emilian model" [Brusco, 1982; Amin, 1999], which is marked by the presence of a district-like industrial system, a well defined spirit of entrepreneurship and an equally strong and deep-rooted unionism. Historically, both MO and RE belong to the Emilia-Romagna areas with the strongest industrial structures since the 1950s. The two LPS have been traditionally the most advanced and richest in Emilia-Romagna in terms of high rates of employment, strong presence of small and medium sized enterprises (SME), very high per-capita income levels compared with the Italian average and good levels of social welfare. The LPS are also characterized by the presence of public organizations that provide funding for services,

[10] Although the data treat these variables separately, we consider the training as part of the organizational activities; for this reason the training is an element to compute (if existing and significant) inside the SBOC phenomenon.

infrastructures, social security, and so on, and contribute to creating a particularly efficient institutional set-up [Putnam *et al.*, 1994; Russo, 1986]. A fundamental role is played by the presence of strong, well rooted and proactive unions, which shape the industrial system.[11] In a strategic framework in which conflicts and industrial relations problem exist, relations at firm level between management and union representatives are driven by participative and cooperative behaviours in the pursuit of mutual aims and benefits [Seravalli, 2001; Antonioli *et al.*, 2004; Antonioli *et al.*, 2010].

Our empirical analysis is conducted using a single data set, which results from the match of two surveys on manufacturing firms located in MO and RE. The criteria we adopted for the identification of the population and the sample were: *(i)* firms with at least 50 employees; *(ii)* firms belonging to manufacturing sectors according to the ISTAT ATECO 2002 classification[12]; *(iii)* presence of union representatives to be interviewed. The data were provided by union representatives, through face-to-face interviews, and refer to 2004 - 2006 period. Both the surveys are unique sources of information about firms' structural characteristics, workforce composition, innovation activities and industrial relations[13].

Tables A.1a and A.1b show the population and the sample used in the empirical analysis. A version of the Cochran test (Cochran, 1977) proves that the population is well represented by the sample of firms interviewed. However, some distortions remain and they are mainly related to the relatively sparer presence of union representatives within small firms (50-99 employees). The statistic test for the representativeness offered in table A.2 show satisfactory results in terms of sample/population ratio concerning both sectors and size, as well as geographical areas.

In the empirical analysis we follow two different lines of investigation. First, we run an OLS estimation, with the aim of verifying the existence and the robustness of the relationship between the skill-ratio, our dependent variable, and innovations and industrial relations factors.

The OLS model is based on the following regression function:

$$[\textit{Skill-ratio: } \ln(WC/BC)] = \alpha + ß_{0i}[\textit{structural variables}] + ß_{1i}[\textit{industrial relations}] + ß_{2i}[\textit{training}] + ß_{3i}[\textit{organizational variables}] + ß_{4i}[\textit{technological variables}] + ß_{5i}[\textit{ICT variables}] + \varepsilon_i \quad (1)$$

where the dependent variable is the skill-ratio or the share of White Collars (WC) on Blue Collars (BC) workers, in logarithm; *i* represents each observation; *ß* represents a vector of coefficients,

[11] This is especially true for the role of CGIL, the union with socialist and communist origins.

[12] The sectors are: food, textiles and clothing, wood, chemicals, non-metallic mineral products, machinery, other industries. The ISTAT ATECO classification coincides with the NACE Rev1.1 and thus with ISIC Rev3.1.

[13] The two surveys are also used in a recent work by Antonioli *et al.* (2009), to investigate the relationship between innovation types, industrial relations and working conditions.

which are related to each vector of independent variables (covariates); α represents the constant of the model and ε represents the error term.

Among the covariates we can distinguish (see tab.A.3 in Appendix for detailed descriptions of the variables): (i) firm structural variables, which give information on sector, size, typology, performance, as well as labour contracts (labour flexibility); (ii) variables of the industrial relations system; (iii) training activities variables; (iv) technological innovation variables, which include input (R&D) and output (incremental/radical product/process innovations) of technological process; ICT variables and, finally, (v) organizational innovation variables[14, 15].

The above mentioned OLS analysis can be considered a first step of our empirical work. After having assessed the relations between the different sets of explicative variables and the skill ratio we turn to verify the same kind of relations when the dependent variables are respectively the numerator and denominator of the skill ratio, that is to say the WC and BC workers. Like other authors [Betts, 1997; Adams, 1999; De Laine *et al.*, 2000; Bratti and Matteucci, 2004; Piva *et al.*, 2005], in fact, we believe that the most appropriate estimation approach is the Zellner's (1962) seemingly unrelated regression (SUR), although we have no panel but cross-section data. In the SUR framework, both intercepts and slope coefficients are free to differ among different classes of workers, therefore we can capture the different relations that exist between innovation activities and respectively WC and BC workers. On the hypothesis that the right-hand side of the equation is independent of the error term and that the errors are correlated, the SUR model is more efficient respect to OLS one.

The SUR empirical model is based on the following equations:

$$\begin{cases} \ln(WC)=\alpha_{WC} + ß_{WC,0i}[\textit{structural variables}] + ß_{WC,1i}[\textit{industrial relations}] + ß_{WC,2i}[\textit{training}] + ß_{WC,3i}[\textit{organizational variables}] + ß_{WC,4i}[\textit{technological variables}] + ß_{WC,5i}[\textit{ICT variables}] + \varepsilon_{WC,i} & (2) \\ \ln(BC)=\alpha_{BC} + ß_{BC,0i}[\textit{structural variables}] + ß_{BC,1i}[\textit{industrial relations}] + ß_{BC,2i}[\textit{training}] + ß_{BC,3i}[\textit{organizational variables}] + ß_{BC,4i}[\textit{technological variables}] + ß_{BC,5i}[\textit{ICT variables}] + \varepsilon_{BC,i} & (3) \end{cases}$$

[14] It is worth pointing out the fact that different innovation activities and industrial relations are thought to encompass several levels. In fact, it is possible to investigate the relationship between skills and the synthetic indexes of industrial relations, training, organizational changes, technological change and ICT, but we can also analyse the relationship between skills and the specific variables (components) which are used to construct the synthetic indexes. Every synthetic index, indeed, is build by an additive combination of exhaustive, very specific, variables (tab. A.3 in Appendix).

[15] It is convenient to underline that frequently in the skill bias empirical literature the innovation variables, especially the organizational ones, have been measured as simple dummies [Caroli and Van Reenen, 2001; Bauer and Bender, 2004; Piva *et al.* 2005]. In our case, the richness of micro-level data not only reduces, to some extent, the likelihood of relevant variables being omitted, but also gives an original and essential value added to this study.

where the dependent variable is the logarithm of the WC and BC workers; ***I, ß,*** *α* and *ε* have the same meaning they assume in equation (1).

3. Results

The results of the OLS and SUR econometric exercises are reported respectively in tables 1, 2, 3 and 4, 5, 6.

First, it should be stressed that we settled up different specifications for each synthetic innovation index and then we ran a regression with all the innovative indexes (synthetic indexes, tables 1 and 4). Second, in order to recognize the specific explanatory variables, we estimated the model using the main variables utilized to build the synthetic innovation indexes (specific indexes, tables 2 and 5). Third, we also ran regressions with multiplicative interaction terms between different innovation indexes (complementarities, tables 3 and 6)[16].

Starting with the OLS results (tables 1 to 3) we have to highlight that the dummy identifying the LPS of Modena (MORE) is significant and negatively related with the skill ratio, meaning that in general the firms located in Modena employ a lower proportion of WC with respect to BC when compared to the Reggio Emilia ones. In addition, a strong relation for both the LPSs is shown by the index that measure the trend of flexible labour contracts (TREND_FLC) which reveals a robust complementary relation with the skill-ratio.

Considering now the variables capturing the innovation activities aspects we note a strong relation between skill-ratio and training activities (TRAIN). The robustness of the relationship is verified also for the organizational changes (ORG). On the contrary, the relations between the pure technology (TECH) and the ICT (ICT) indexes are weaker than for the two preceding indexes, which mainly capture organizational aspects. These latter, according to this first set of results (table 1), seem to contribute more in explaining the occupational composition than the technological aspects of the innovation activities. Finally, the industrial relations index (IND_REL), which represents the intensity of good quality climate in firm level industrial relations, does not influence the workforce composition.

In table 2 we disaggregate the different indexes in their components. The utilization of innovative specific indexes rather than innovative synthetic indexes aims to find the specific

[16] It is worth noting that the presentation of the econometric results is more qualitative than quantitative, because we are not interested in finding elasticises, also because of the variables nature; rather we are interested in pointing out the main associations among the dependent and the covariates in a multivariate context. A second point concerning the way the results are displayed is related to the structural variables, whose coefficients are not reported. We simply comment structural variables main results in the text.

components that drives the significance of the synthetic indexes. As we can see every innovative synthetic variable encloses a key element, with the exception of the ICT variable, that mainly drives its sign and significance. The same hold for industrial relations: the presence of firm level bargaining (FL_BARG) is significant, with positive sign.

Finally, specifications 5 in tables 1 and 2 are used to test the robustness of the results obtained in previous estimations. The whole set of covariates is used and as we can see only the training variables, both the synthetic index and the element capturing the competencies developed through training activities, are significant. Such a result does not come unexpected: the higher the intensity in training activities, the higher is the skill ratio or, equivalently, the higher the proportion of skilled workers (WC) with respect to the unskilled ones (BC).

TABLE 1 – *OLS results with innovative synthetic indexes (Dependent: ln(WC/BC))*

Specifications	1	2	3	4	5
Dependent Variable	ln(WC/BC)	ln(WC/BC)	ln(WC/BC)	ln(WC/BC)	ln(WC/BC)
Controls	**yes**	**yes**	**yes**	**yes**	**yes**
TRAIN	**	-	-	-	*
ORG	-	**	-	-	
TECH	-	-	*	-	
ICT	-	-	-	*	
IND_REL					
Constant	***	***	***	***	***
OBS	235	241	241	241	235
R2	0.173	0.165	0.160	0.157	0.190
F (P_Value)	3.793 (0.000)	3.412 (0.000)	3.664 (0.000)	3.483 (0.000)	3.370 (0.000)
VIF	1.39	1.38	1.40	1.38	1.47

Notes: only the level of significance of the coefficients and their signs, when negative, are reported: * significant at 10%, ** significant at 5%, *** significant at 1%; the coefficients but full results are available upon request; empty cell means the variable is not significant at least at 10%; - represents variables not included in the estimation; controls are size dummies, sector dummies, LPS dummy, firm typology, labour contracts (labour flexibility), performance; delocalization dummy and strategy dummies (see table A.3 in Appendix); regressions have been conducted with standard errors robust to heteroskedasticity; VIF is the Variance Inflation Factor and it represents a 'test' to recognize the existence of multicollinearity when the threshold of 10 is passed.

TABLE 2 – *OLS results with innovative specific indexes (Dependent: ln(WC/BC))*

Specifications	1	2	3	4	5
Dependent Variable	ln(WC/BC)	ln(WC/BC)	ln(WC/BC)	ln(WC/BC)	ln(WC/BC)
Controls	**yes**	**yes**	**yes**	**yes**	**yes**
MANUNI_REL					
BTC					
FL_BARG	*****				
INDREL_TREND					
TRAIN_ADV		**-**	**-**	**-**	
TRAIN_RATIO		**-**	**-**	**-**	
TRAIN_COMP	******	**-**	**-**	**-**	******
OUTSORC	**-**		**-**	**-**	
INSORC	**-**		**-**	**-**	
FIRM_REL	**-**		**-**	**-**	
ORG_PROD	**-**		**-**	**-**	
ORG_LAB	**-**	******	**-**	**-**	
REW_TOT	**-**		**-**	**-**	
TECH_INP	**-**	**-**	******	**-**	
TECH_OUT	**-**	**-**		**-**	
ICT_PROD	**-**	**-**	**-**		
ICT_COM	**-**	**-**	**-**		
ICT_MAN	**-**	**-**	**-**		
Constant	******	*******	*******	*******	******
OBS	154	240	241	239	153
R2	0.252	0.197	0.167	0.170	0.296
F	3.568	2.852	3.125	2.996	2.972
(P_Value)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
VIF	1.48	1.40	1.42	1.38	1.56

Notes: only the level of significance of the coefficients and their signs, when negative, are reported: * significant at 10%, ** significant at 5%, *** significant at 1%; the coefficients but full results are available upon request; empty cell means the variable is not significant at least at 10%; **-** represents variables not included in the estimation; controls are size dummies, sector dummies, LPS dummy, firm typology, labour contracts (labour flexibility), performance; delocalization dummy and strategy dummies (see table A.3 in Appendix); regressions have been conducted with standard errors robust to heteroskedasticity; VIF is the Variance Inflation Factor and it represents a 'test' to recognize the existence of multicollinearity when the threshold of 10 is passed.

As the third research question suggests, we also run regressions with multiplicative interaction terms in order to verify the existence of complementarities between the several innovative synthetic terms and the skill-ratio (table 3). As expected, for all the specifications, relations between the interaction terms and the skill-ratio are reinforced versions of those obtained without interactions and this is especially true for terms that include the training synthetic index. Hence, on the role of complementarities inside the skill-bias phenomenon, table 3 confirms important results already found by Piva *et al.* (2006).

TABLE 3 – *OLS results with innovative interaction terms (Dependent: ln(WC/BC))*

Specifications	1	2	3	4	5	6
Dependent Variable	ln(WC/BC)	ln(WC/BC)	ln(WC/BC)	ln(WC/BC)	ln(WC/BC)	ln(WC/BC)
Controls	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**
TRAIN*ORG	***	-	-	-	-	-
TRAIN*TECH	-	***	-	-	-	-
TRAIN*ICT	-	-	***	-	-	-
ORG*TECH	-	-	-	**	-	-
ORG*ICT	-	-	-	-	**	-
TECH*ICT	-	-	-	-	-	**
Constant	***	***	***	***	***	***
OBS	235	235	235	241	241	241
R2	0.185	0.178	0.181	0.166	0.167	0.164
F (P_Value)	3.859 (0.000)	3.892 (0.000)	4.015 (0.000)	3.607 (0.000)	3.538 (0.000)	3.772 (0.000)
VIF	1.39	1.40	1.40	1.38	1.39	1.40

Notes: only the level of significance of the coefficients and their signs, when negative, are reported: * significant at 10%, ** significant at 5%, *** significant at 1%; the coefficients but full results are available upon request; empty cell means the variable is not significant at least at 10%; **-** represents variables not included in the estimation; controls are size dummies, sector dummies, LPS dummy, firm typology, labour contracts (labour flexibility), performance; delocalization dummy and strategy dummies (see table A.3 in Appendix); regressions have been conducted with standard errors robust to heteroskedasticity; VIF is the Variance Inflation Factor and it represents a 'test' to recognize the existence of multicollinearity when the threshold of 10 is passed.

As noted in the previous paragraph, the utilization of the OLS method is functional to have an important overview on the principal significant variables. In what follows, with the SUR approach we aim to disentangle the role of innovation activities on each occupational components: WC and BC.

Starting from the structural variables, although not reported for brevity[17], we have common results in all the three tables (tables 4 to 6). The main evidence concerns the LPS dummy (MORE). It is highly significant with a negative sign for WC and positive for BC, confirming that in MO the relative level of WC (BC) is lower (higher) with respect to RE. Contextually, also the variable measuring the trend of flexible labour contracts (TREND_FLC) is significant both for WC (positively) and for BC (negatively) workers. How can we explain this outcome? If within firm an increase in the diffusion of flexible contracts[18] is essential to explain skills, it is possible that the source is a "generational effect" (or generational turnover): the diffusion of flexible contracts regards increasingly executive and office workers for the reason that there is a large increase in the supply of more educated workers due to increasing average education [Checchi, 2001; Acemoglu, 2002].

[17] Detailed results are available upon request.

[18] On the basis of the data, about 85% of flexible contracts concerns BC workers while only 15% concerns WC workers.

Turning now to the variables of main interest for the present work, we note a significant impact of the innovation activities widely conceived: training policies, organizational, technological and ICT activities (tables 4 and 5). With the first two specifications in tables 4 and 5 (1a and 1b, 2a and 2b) we aim to verify the SBOC hypothesis, while the third and fourth specifications (3a and 3b, 4a and 4b) are used to verify the robustness of the SBTC hypothesis. The caveat to be reminded is that we are dealing not with causal effects but simply with relationships in a multivariate context.

In specification 1 we notice that the training variable (TRAIN) affects the demand for WC and BC with the expected signs and proves to be significant among the skilled. When we consider the synthetic index TRAIN and we use its components we observe that the sign of the index is mainly driven by the component that captures the percentage of employees involved in training programmes (coverage indicated as TRAIN_RATIO) as well as by the variable that measures the whole competencies that the training programmes aim to develop, that is the index of training competencies (TRAIN_COMP). This last variable has also a negative effect on BC workers that does not emerge in the synthetic index. Results concerning the training policies are consistent with the idea that firms which realized training courses for a wide range of employees and at the same time invested more resources on training are those needing more skilled workers.

In addition, we note that the organizational innovation variable (ORG) (specification 2) proves to be extremely significant in determining redundancy among the unskilled. Again when we disaggregate the index in its components we find that the sign of the synthetic index is driven by specific components: the specific index of production networking, that is the relation with clients and suppliers (on furniture, assistance, changing technological equipment, exchange of technical and commercial knowledge/information, etc.) (FIRM_REL), shows a weak negative effect on BC, while the measure of organizational changes in work organization (job rotation, delegation, continuous training, etc.) (ORG_LAB), shows a strong positive effect on WC. Thus, organizational changes have a negative relation with unskilled workers, but this is true only for the synthetic index. Among specific indexes, ORG_LAB is the most significant variable; this variable, in fact, has a positive relation with the skilled side of the workforce: it appears that new organizational practices, even if not directly linked to the production process, are important explanatory variables for upskilling. Our empirical results seem to support, although partially, the SBOC hypothesis. In particular, changes labour organization appear to have a strong relation with high skilled workers. On the other hand, the organizational changes synthetically represented by the variable ORG do not show to support the SBOC hypothesis, rather they seem to negatively influence the less skilled workers. Thus, as a whole the ratio between WC and BC could increase not because of an upskilling effect, but just because the workforce reshaping in case of changes in labour organization penalize BC without great influence on WC.

Changes in firm organization, which lead to structures characterized by flexibility, delayering and participation of workers to decision processes, reduce the need for less skilled workers. In fact, various empirical studies show that organizational changes have negative effects on less skilled workers [Caroli et al., 2001; Caroli and Van Reenen, 2001; Piva and Vivarelli, 2004], rather than a positive one on skilled. Moreover, as just pointed out by Piva *et al.* (2005), organizations results are consistent with a view of Italy that rooted in the ideas of Fuà (1988), who underlines the centrality of the "organizational-entrepreneurial" factor in re-patterning the profile of those Italian firms which cannot rely on their own R&D as the sole source of change.

With specifications 3 and 4 we test the significance of the SBTC hypothesis. Specification 3 in particular examines the intensity in technological innovations, and the results suggest positive and significant effects of the explanatory variable (TECH) on skilled workers. As we can see in table 5, when we disaggregate TECH in its components, we discover that the sign of the synthetic index is mainly due to innovation intensity concerning the input, or R&D (TECH_INP), rather than the output (TECH_OUT) of technological development. Such a result is in line with part of the international empirical literature discussed above, in particular it is in line with the evidence provided for Anglo-Saxon countries. Although the result seems puzzling for the Italian context we are able, thanks to the richness of our data, to find which are the specific technological innovation factors related to WC workers. Indeed, it appears that firms with high index of R&D (TECH_INPUT) have also high levels of WC workers. The same strong and positive relation emerges when we consider the index of ICT adoption (ICT) (specification 4), and in this case we perceive that a central component that drives the significance of the synthetic variable is ICT_MAN, that captures the introduction of systems using ICT in management-integration (such as EDI, Electronic Data Interchange, MRP, Material Requirements Planning, etc.). Therefore it seems that ICT adoption needs skilled workers because, as pointed out by some researchers, it gives to the firm superior performance [Bresnahan *et al.*, 2002; Aral and Weill, 2005] if it is implemented and used by skilled workers rather than unskilled ones [Acemoglu, 2002]. In synthesis, these results confirm the strong and deep relation between R&D and skills, thus supporting the general skill biased nature of technological change.

Finally, specification 5 (5a and 5b) is used to test the robustness of the results obtained in the previous estimations. All the innovative variables are jointly used and as we can see those variables significant in the preceding specifications are almost always significant in this last one, notwithstanding the sharp reduction in the number of observations in table 5.

Now we turn to the outcomes obtained in the several equations analyzed by the synthetic and disaggregated industrial relations variables. We have chosen to insert the industrial relations in all the regression, similar to a structural variable, notwithstanding that industrial relations could be a good instrument for the innovative variables[19]. Results are not totally consistent as for the innovative variables, but they are anyway interesting. The synthetic index is not significant, while the disaggregated components are somewhat significant, with only two of them significant across several specifications: the index measuring the interaction between management and union representatives on several items (production, quality, employment, working hours, etc.) (MANUNI_REL); the index measuring the trend in industrial relations quality with respect to the preceding year (INDREL_TREND). The first one has a positive sign for BC, while the second one has always a negative sign both for WC and BC. The mixed evidence of the industrial relations aspects on occupational composition does not allow simple interpretations. However, this results do not come unexpected [Antonioli *et al.* 2004]. Indeed, we may argue that local unions power translates into the capacity to make union voice more effective within firms with high levels of BC, in the hypothesis that BC are more unionized than WC. At the same time it is possible that management is more inclined to discuss unions instances where unions are representatives of a large part of BC. The negative sign associated to the industrial relations trend may simply capture a specific time effect, given that the perceived trend declared by the respondents is on two years. Additional empirical evidence and maybe more time spanning would be necessary to disentangle this topic.

[19] Antonioli *et al.* (2010) have found that industrial relations show an indirect effects on labour productivity, spurring innovation activities.

TABLE 4 – *SUR results with innovative synthetic indexes (Dependents: lnWC and lnBC)*

Specifications	1a	1b	2a	2b	3a	3b	4a	4b	5a	5b
Dependent Variable	lnWC	lnBC	lnWC	lnBC	lnWC	lnBC	lnWC	lnBC	lnWC	lnBC
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
TRAIN	**		-	-	-	-	-	-	*	
ORG	-	-		(-) ***	-	-	-	-		(-) **
TECH	-	-	-	-	**		-	-		
ICT	-	-	-	-	-	-	**		**	
IND_REL										
Constant	***	***	***	***	***	***	***	***	***	***
R-SQ	0.5829	0.6549	0.5776	0.6694	0.5813	0.6613	0.5854	0.6598	0.5929	0.6639
OBS	235		241		241		241		241	

Note: only the level of significance of the coefficients and their signs, when negative, are reported: * significant at 10%, ** significant at 5%, *** significant at 1%; the coefficients are not reported for shortness but full results are available upon request; empty cells mean the variable is not significant at least at 10%; - represents variables not included in the estimation; controls are size dummies, sector dummies, LPS dummy, firm typology, labour contracts (labour flexibility), performance; delocalization dummy and strategy dummies (see table A.3 in Appendix); all regressions are more efficient respect to OLS estimations according to the Breusch-Pagan's test: 1 - $\chi^2(1)$= 28.135***; 2 - $\chi^2(1)$= 28.898***; 3 - $\chi^2(1)$= 29.426***; 4 - $\chi^2(1)$= 30.932***; 5 - $\chi^2(1)$= 29.093***.

TABLE 5 – *SUR results with innovative specific indexes (Dependents: lnWC and lnBC)*

Specifications	1a	1b	2a	2b	3a	3b	4a	4b	5a	5b
Dependent Variable	lnWC	lnBC	lnWC	lnBC	lnWC	lnBC	lnWC	lnBC	lnWC	lnBC
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
MANUNI_REL				**		**		**		
BTC		***								**
FL_BARG	*									
INDREL_TREND	(-)**	(-)**		(-)**		(-)**		(-)**	(-)**	(-)*
TRAIN_ADV			-	-	-	-	-	-		
TRAIN_RATIO	**		-	-	-	-	-	-	*	
TRAIN_COMP	*	(-)*	-	-	-	-	-	-	*	(-)**
OUTSORC	-	-			-	-	-	-		(-)**
INSORC	-	-			-	-	-	-		
FIRM_REL	-	-		(-)*	-	-	-	-		
ORG_PROD	-	-			-	-	-	-	(-)*	
ORG_LAB	-	-	***		-	-	-	-		
REW_TOT	-	-			-	-	-	-		
TECH_INP	-	-	-	-	***		-	-	**	
TECH_OUT	-	-	-	-			-	-		
ICT_PROD	-	-	-	-	-	-				
ICT_COM	-	-	-	-	-	-				
ICT_MAN	-	-	-	-	-	-	*		**	
Constant	***	***	***	***	***	***	***	***		
R-SQ	0.6527	0.6755	0.5978	0.6884	0.5885	0.6756	0.5927	0.6781	0.6912	0.6948
OBS	154		240		241		239		153	

Note: only the level of significance of the coefficients and their signs, when negative, are reported: * significant at 10%, ** significant at 5%, *** significant at 1%; the coefficients are not reported for shortness but full results are available upon request; empty cells means the variable is not significant at least at 10%; **-** represents variables not included in the estimation; controls are size dummies, sector dummies, LPS dummy, firm typology, labour contracts (labour flexibility), performance; delocalization dummy and strategy dummies (see table A.3 in Appendix); all regressions are more efficient respect to OLS estimations according to the Breusch-Pagan's test: 1 - $\chi^2(1)$= 23.170***; 2 - $\chi^2(1)$= 30.924***; 3 - $\chi^2(1)$= 34.021***; 4 - $\chi^2(1)$= 35.007***; 5 - $\chi^2(1)$= 23.938***; $\chi^2(1)$= 27.652***.

As already pointed out, we also ran regressions with multiplicative interaction terms between the different innovation indexes in order to 'test' the existence of complementarities between technological change, organizational change and skills, as the third research question suggests.

We report the main outcomes in table 6. Several recognizable complementarities emerge, among the different innovation indexes and the skilled and unskilled workforce. Complementarities are more evident when variables concerning the SBOC are used, that is organizational changes and training innovation activities; not by chance the interaction term between these indexes (TRAIN and ORG) is the best explanatory variable overall (specification 1). Training policies and *HPWP* show strong interaction with the occupational composition, as it has been widely theoretically analyzed within evolutionary theory of the firm by Teece and Pisano (1994): firms which realize important and wide training courses as well as implement changes in organization are firms with an high WC/BC ratio.

In addition, others interaction terms reinforce the result previously obtained without interactions: TRAIN*TECH and TRAIN*ICT prove to be strongly significant when the dependent variable is a proxy of skilled workers (WC) (specification 2 and 3), while interactions between ORG and technology (both TECH and ICT) show fewer complementarities with WC and negative relation with the BC (specification 4 and 5). The evidence also points to a certain complementary nature between the SBTC and SBOC hypotheses as the results of specifications 4 and 5 suggests. The complementary nature of organisational and technological changes does not only exerts its effect on firm performance [Pavitt *et al.*, 1989; Milgrom and Roberts, 1990; Black and Lynch, 2001], but also on the workforce composition [Aghion *et al.*, 1999; Bresnahan *et al.*, 2002].

As a whole, the last estimates with interaction terms show systematic and super-additive effects which delineate synergic linkages between the different innovation activities, especially due to the interaction with the training activities and the organizational changes. Our result is coherent with various international researches [Caroli and Van Reenen, 2001; Bresnahan *et al.*, 2002; Aral and Weill, 2005] and also with the only one carried out for Italy [Piva *et al.*, 2006]: in this case the authors indeed find a super-additive effect between technology and organization that is driven by new organizational practices in machinery industries.

TABLE 6 – *SUR results with innovative interaction terms (Dependents: lnWC and lnBC)*

Specifications	1a	1b	2a	2b	3a	3b	4a	4b	5a	5b	6a	6b
Dependent Variable	lnWC	lnBC	lnWC	lnBC	lnWC	lnBC	lnWC	lnBC	lnWC	lnBC	lnWC	lnBC
Controls	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**
TRAIN*ORG	***	(-) **	-	-	-	-	-	-	-	-	-	-
TRAIN*TECH	-	-	***		-	-	-	-	-	-	-	-
TRAIN*ICT	-	-	-	-	***		-	-	-	-	-	-
ORG*TECH	-	-	-	-	-	-	*	(-) **	-	-	-	-
ORG*ICT	-	-	-	-	-	-	-	-	**	(-) *	-	-
TECH*ICT	-	-	-	-	-	-	-	-	-	-	**	
Constant	***	***	***	***	***	***	***	***	***	***	***	***
R-SQ	0.5839	0.6604	0.5873	0.6549	0.5898	0.6548	0.5800	0.6664	0.5820	0.6647	0.5857	0.6610
OBS	235		235		235		241		241		241	

Note: only the level of significance of the coefficients and their signs, when negative, are reported: * significant at 10%, ** significant at 5%, *** significant at 1%; the coefficients are not reported for shortness but full results are available upon request; empty cells means the variable is not significant at least at 10%; - represents variables not included in the estimation; controls are size dummies, sector dummies, LPS dummy, firm typology, labour contracts (labour flexibility), performance; delocalization dummy and strategy dummies (see table A.3 in Appendix); all the five regressions verify to be more efficient respect to OLS estimations according to the Breusch-Pagan’s test: 1 - $\chi^2(1)$= 26.627***; 2 - $\chi^2(1)$= 28.064***; 3 - $\chi^2(1)$= 28.070***; 4 - $\chi^2(1)$= 28.542***; 5 - $\chi^2(1)$= 28.506***; 6 - $\chi^2(1)$= 29.491***.

4. Conclusions

During the lasts forty years the more industrialized countries have experienced a sharp increase in the inequality, both in terms of wage and occupational structure, between skilled and unskilled workers.

With regard to the occupational structure, the number of more skilled workers is appreciably augmented; on the contrary the amount of less skilled seems to be decreased. Most part of empirical evidence finds in technological and organizational changes a robust explanation for the upskilling phenomenon. For Anglo-Saxon countries the technological explanation prevails, while for continental European countries some studies point out to the organizational explanation, which sometimes shows a negative effect on less skilled workers rather than a positive one on skilled. Several authors evidence also the existence of key complementary relations between innovative variables.

The present paper provides further evidence concerning the relations between technological change, organizational change and workforce composition at firm level using original datasets on Italian manufacturing firms located in Emilia-Romagna. We analyse such relations in a multivariate context, although we do not deal with causal effect because of data characteristics, also focusing the attention on firm level industrial relations. The latter can be thought as an important idiosyncratic element of the local production systems analysed, which can potentially influence the occupational structure within firms.

First, the empirical evidence support the hypothesis of the skill-biased technological change. Technological innovations on the input side (R&D expenditures) and ICT (mainly systems that use ICT in managerial-integration) are robustly associated with high levels of white collars.

Second, we find partial evidence of the skill-biased organizational change. Indeed, on the one hand the results show that the specific variables that measure changes in labour organization and training activities have strong relationships with skilled workers; on the other hand, the synthetic index capturing organizational change as a whole do not support the SBOC hypothesis, rather it proves to be significant in determining redundancy among the unskilled, consistently with several continental European country's studies.

Third, in addition to the SBTC and SBOC hypotheses distinctly investigated, we prove the existence of complementarities considering interactions among technological and organizational innovation activities. As a matter of fact it appears that several innovative variables when interacted have a quite strong linkage with skilled workers. This especially hold for training synthetic index, which seems to be complementary to all the other innovative variables.

Finally, the mixed evidence regarding industrial relations and occupational composition does not allow simple interpretations. We find that the local unions have power and good capacity to confront with management within firms with a large number of blue collars and, at the same time, that a negative trend in industrial relations is experienced in firms with more blue collar workers, suggesting the emergence of some difficulties in maintaining the social dialogue.

In synthesis, the results here obtained highlight and confirm, for the local production systems taken into consideration, the importance of the technological and organizational change as explanation of the recent upskilling, as international studies demonstrate for other western labour markets. In addition, the richness of our data allows enriching the empirical analysis considering potentially relevant idiosyncratic factors, such as firm level industrial relations.

Appendix

TABLE A.1A – Firms population in Modena and Reggio Emilia (% and absolute value)

Sectors	Size classes			Total	Absolute value
	50-99	100-249	>249		
Food	4,52	3,14	1,18	*8,84*	*45*
Textile and Clothing	4,91	1,18	1,38	*7,47*	*38*
Wood, Other Industries	4,52	1,57	1,38	*7,47*	*38*
Chemical	3,93	3,14	0,59	*7,66*	*39*
Non-metallic mineral	6,68	5,89	4,13	*16,70*	*85*
Machineries	29,67	14,73	7,47	*51,87*	*264*
Total	*54,22*	*29,67*	*16,11*	*100,00*	
Absolute value	*276*	*151*	*82*		*509*

TABLE A.1B – Interviewed firms in Modena and Reggio Emilia (% and absolute value)

Sectors	Size classes			Total	Absolute value
	50-99	100-249	>249		
Food	2,83	5,30	2,12	*10,25*	*29*
Textile and Clothing	2,83	1,41	1,06	*5,30*	*15*
Wood, Other Industries	2,12	2,83	2,47	*7,42*	*21*
Chemical	4,24	3,53	1,06	*8,83*	*25*
Non-metallic mineral	7,07	10,60	7,07	*24,73*	*70*
Machineries	14,84	19,08	9,54	*43,46*	*123*
Total	*33,92*	*42,76*	*23,32*	*100,00*	
Absolute value	*96*	*121*	*66*		*283*

TABLE A.2 – Marbach test for the interviewed firms

	N=population size	n=sample size	Cochran Test Margin of error θ
SECTORS			
Food	45	29	0,1120
Textile and Clothing	38	15	0,2036
Wood, Other Industries	38	21	0,1479
Chemical	39	25	0,1214
Non-metallic mineral	85	70	0,0505
Machineries	264	123	0,0660
SIZE CLASSES			
50-99	276	96	0,0826
100-249	151	121	0,0407
>249	82	66	0,0547
LOCAL PRODUCTION SYSTEM (LPS)			
Modena	291	150	0,0558
Reggio Emilia	218	133	0,0543
Total	509	283	*0,0396*

TABLE A.3 – Descriptive statistics

Variables	*Description*	*Min*	*Max*	*Mean*
	Dependent Variables			
	Occupational composition			
lnWC/BC	Logarithms of the White Collars/Blue Collars ratio	*-4,37*	*4,26*	*-0,83*
lnWC	Logarithms of the number of White Collar workers within the local unit	*0*	*6,93*	*3,60*
lnBC	Logarithms of the number of Blue Collar workers within the local unit	*0*	*7,52*	*4,42*
	Controls and Explanatory Variables			
	Structural Variables			
Local Production System Dummy (**MORE**)	Binary variables (0,1)	*0*	*1*	*/*
Sectors Dummies (Food , Textile, Wood and Other Industries, Chemical, Non-metallic minerals, Machineries)	Binary variables (0,1)	*0*	*1*	*/*
Size Dummies (50-99, 100-249, 250-499, >499)	Binary variables (0,1)	*0*	*1*	*/*
Firm Typology Dummies (private firm, industrial group, cooperative firm, cooperative group; private firm/group, cooperative firm/group)	Binary variables (0,1)	*0*	*1*	*/*
Performance Indicators from questionnaire: Productivity (**PERF_PROD**), Revenue (**PERF_PROV**), Profit (**PERF_REV**), Investment (**PERF_INV**)	Indexes: each type of performance is ranked on a -5 (worse than the preceding year)+5 (better then the preceding year) scale	*-5*	*5*	*/*
Percent of International Turnover (**FOR_PROF**)	Percentage of turnover made on international markets. Rescaled on interval (0-1)	*0*	*1*	*0,44*
Delocalization (d) (**DELOC**)	Binary variable (0,1)	*0*	*1*	*0,25*
Cost-Price Strategy (d) (**CP_STR**)	Binary variable (0,1)	*0*	*1*	*0,58*
Other (Technology, Quality, Brand and Variety) Strategy (d) (**OTHER_STR**)	Binary variable (0,1)	*0*	*1*	*0,92*
Labour Contract Flexibility - ratio (**RATIO_LCF**)	Ratio of employees with flexible labour contracts on total employees	*0*	*103, 42*	*13,40*
Conversion of Flexible Labour Contracts in Long-lasting Ones (**CONV_LCF**)	Index: percentage of workers who are hired permanently after the flexible contract expires	*0*	*100*	*49,41*
Variation in Internal Flexibility (**TREND_LCF**)	Composite index capturing the variation I several forms of flexibility: Temporal, Functional, Wage, Organizational	*1*	*3*	*2,27*
	Industrial Relations			
IND_REL (interval 0-1)	Synthetic index of good quality industrial relations	*0,15*	*0,94*	*0,56*
Management/Union Interaction on Issues (**MANUNI_REL)**	Index: interaction between management and union representatives (no interaction, information, consultation, negotiation) on several issues (e.g. production, quality, employment, working hours, etc…)	*1*	*3,57*	*2,00*
Bilateral Technical Commissions (d) (**BTC**)	Binary variable (0,1): 1 if a BTC exists	*0*	*1*	*0,25*
Firm Level Bargaining (d) (**FL_BARG**)	Binary variable (0,1): 1 if a second level formal agreement has been signed in 2004 (RE) or during 2004-2006 (MO)	*0*	*1*	*0,78*
Trend in Industrial Relations	Index: trend of the industrial relations compared to the preceding year	*1*	*3*	*2*

(**INDREL_TREND**)				
	Training			
INNO_TRAIN…. (interval 0-1)	Composite index capturing the intensity in training activities Mean of the following indexes:	*0*	*0,97*	*0,42*
….Training Coverage (**TRAIN_RATIO**)	Index: percentage of employees involved in training programmes (0 nobody; 1=1-24%; 2=25-49%; 3=50-74%; 4=75-100%)	*1*	*4*	*2,23*
Training Advantages (**TRAIN_ADV**)	Index: advantages for employees involved in training activities Interval (0-1).	*0*	*1*	*0,39*
Index of Training Competencies (**TRAIN_COMP**)	Index: based on the whole competencies the training programmes aim to develop. Interval (0-1).	*0*	*1*	*0,39*
	Organizational Innovation			
INNO_ORG (interval 0-1)	Composite index capturing the intensity in organizational innovations. Construction based on the following organizational indexes.	*0*	*0,75*	*0,26*
Out-sourcing (**OUTSORC**)	Index: intensity of out-sourcing in ancillary activities, production support activities and production activities	*0*	*3,79*	*1,27*
In-sourcing (**INSORC**)	Index: intensity of in-sourcing in ancillary activities, production support activities and production activities	*0*	*3,89*	*0,34*
Relations with Client and Suppliers (**FIRM_REL**)	Index: relations with clients and/or suppliers on furniture, assistance, changing technological equipment, exchange of technical and commercial knowledge/information etc…	*0*	*0,72*	*0,24*
Organizational practices in production (**ORG_PROD**)	Index: Changes in organizational practices in production (quality circles, team working, just in time, total quality management)	*0*	*1*	*0,22*
Organizational practices in labour services (**ORG_LAB**)	Index: Changes in organizational practices in labour services (job rotation, delegation, continuous training, etc…)	*0*	*0,91*	*0,28*
Reward System (**REW_TOT**)	Individual and collective reward in 2004 (RE) or during 2004-2006 (MO)	*0*	*1*	*0,40*
	Technological Innovation			
INNO_TECH…. (interval 0-1)	Composite index capturing the intensity in technological innovations Mean of the following indexes:	*0*	*1*	*0,55*
… Input technological innovations (**TECH_INP**)	Index: it synthesizes the information about innovation input (formal R&D division, R&D activities, resources and employees involved in R&D activities, collaborations with other firms on R&D for Reggio Emilia; formal R&D division and collaborations with other firms on R&D for Modena). Interval (0-1).	*0*	*1*	*0,65*
… Output technological innovations (**TECH_OUT**)	Index: it synthesizes the information about innovation output (dummies on: Process Innovation, Product Innovation, Quality Control Innovation, Radical Innovation, Incremental Innovation). Interval (0-1).	*0*	*1*	*0,46*
	ICT			
INNO_ICT… (interval 0-1)	Composite index capturing the intensity in ICT adoption Mean of the following indexes:	*0*	*1*	*0,67*
….ICT in Production (**ICT_PROD**)	Index: introduction of ICT in production. Interval (0-1).	*0*	*1*	*0,58*
ICT in Communication (**ICT_COM**)	Index: introduction of ICT for communication purposes. Interval (0-1).	*0*	*1*	*0,91*
ICT in Management-Integration (**ICT_MAN**)	Index: introduction of systems that use ICT such as EDI, Electronic Data Interchange, EDI (Electronic Data Interchange); MRP (Material Requirements Planning) etc… Interval (0-1).	*0*	*1*	*0,53*

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