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, both technological and organisational changes show specific relations with workforce composition. 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.

More specifically, 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 works as a consequence of technological change. 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 the 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. In addition, another 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 literature review of both theoretical considerations 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 due to an increase in 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's rise in Europe the flip side of the rise of earnings inequality in the US [Freeman, 1995]. This trend is not irrelevant because it has changed the possibilities of occupation for a wide fraction of the population.

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

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. 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]. 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 into question technological change and the potential bias it may induce on labour demand. Many authors see a causal relationship between technological change and this 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 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[1]. In the modern growth theory, many authors have tried to examine technological innovation as endogenous factor [Romer, 1986; Lucas, 1988; Romer, 1990], reconsidering the classical works of Adam Smith and going beyond the concept of the firm with a black-box technology. These more recent approaches, but above all the recent development and diffusion of the economics of innovation along the evolutionary theory of the firm which considers the technology not as a simple information but, instead, 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. Until the Nineties, in fact, the studies focused prevalently on the quantitative effects that technological change had on the workforce, considered as group of individuals with same features. Nevertheless during the last twenty years, on the basis also of empirical evidence, the attention by the economists toward the tasks and the 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 the 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 the skilled side of the workforce; on the other hand there is a substitution relationship between these innovations and unskilled workers; therefore it seems that technological change makes the firm able to achieve superior performance if it is implemented and used by skilled workers rather than unskilled ones[2]

[1] Technological explanation arise from the pioneer observations by Ricardo (1817). Starting from Ricardo (1817), passing through the "compensation theory" of Marx (1867) and the neo-classical Solow growth theory [Solow, 1956], technological change has constantly increased its relevance inside economic theories but often, in particular along the neoclassical mainstream, has been considered a sort of exogenous and simple *multiplicative* factor in the dynamic of economic system.

[2] Analysing the origin of the technology-skill complementarity, Goldin and Katz (1998) observe that, during the first half of the past century, technology has always been associated to unskill biased: products previously manufactured by

[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) [3].

The SBTC is not the only explanation of the recent up-skilling of the workforce. Another hypothesis, not necessarily opposite to the first, has been suggested more recently, 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 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 organization of the firm seems to be far away from the strict and hierarchical tayloristic firm of the beginning of the last century; on the contrary it is much closer to the recent holistic firm characterised by more flexibility and more horizontal coordination [Lindbeck and Snower, 1996], which is the best organizational structure when the economic and social environment facing the firms changes continuously but not drastically [Aoki, 1990]. Thus, organizational change has a direct effect on the human capital of the firms. Following the holistic stream, firms are more oriented toward de-specialized workers with multidimensional capabilities which minimize the routine of the tasks[4]: new organizational practices have increased the demand for qualified human capital and rise emphasis on the "intellectual skills" [Leoni *et al.*, 1998]. The theory of the "Skill-Biased Organizational Change" (SBOC) asserts that decentralization, delayering, collective work, multi-tasking and all what is generally called *High Performance Work Practices (HPWP)* necessitate of more responsible and autonomous workers, that means skilled workers[5].

In addition, some authors consider the technological and the organizational explanation together: in order to introduce important and expensive new technologies, embodied in new machinery or computers, the firms cannot disregard significant changes within the organizational structure[6] [Aghion *et al.*, 1999; Bresnahan, 1999; Caroli, 2001]. So, if a firm wishes to introduce important

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artisans started to be replaced by factory and later by interchangeable parts and the assembly line [Goldin and Katz, 1998; Acemoglu, 2002].

[3] Acemoglu (1998) investigates the role of the supply asserting that is not the technology that settles on the occupational structure (exogenous relationship), but exactly the opposite (endogenous relationship). The technology is therefore stimulated by incentives: the increasing availability of educated workers make profitable the implementation of skill biased technologies.

[4] In this regard see Killick (1995) discussion on "innovation flexibility".

[5] 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.

[6] Even not considering explicitly the skill bias argument, Pini and Santangelo (2008) presupposed a reverse relationship; therefore different types of organization and workers' competence have a different impact on the introduction of exploitative and explorative innovations.

technological innovations to achieve superior performance, it should modify its 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[7] 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 [Guidetti *et al.*, 2006][8].

1.2 Empirical evidences

A large number of studies concerning the relationship between the introduction of technological innovations and workforce composition (SBTC) emerged in the Nineties trying to find an explanation to the rapid increase of skilled workers in the US and in the 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[9] 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 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

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[7] For a review of the theoretical and empirical literature about the role of the complementarities see Guidetti *et al.* (2006).

[8] In addition to the previous approaches, in the literature another important hypothesis exists, alternative or complementary to the previous ones. Trade economists, indeed, support the idea that recent upskilling depends also on globalization, international outsourcing or just trade [Wood, 1994; Feenstra and Hanson, 1996; Slaughter, 2000]. This theory is based on the idea that increased volumes of world trade and FDI have caused an occupational reallocation through different countries: following the comparative advantage theory, unskilled-intensive activities shift to less developed countries while skilled-intensive activities remain in more developed ones [Wood, 1994]. Differently from the SBTC and the SBOC theories and due to a lack of data, empirical results on the relationship between skill bias and globalization are few and also not very satisfactory [Slaughter, 2000, and Feenstra and Hanson, 1996, for the US, and Piva and Vivarelli, 2004, and Helg and Tajoli, 2005, for Italy].

[9] 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].

educated) workers[10]. Other sector-level evidence for the SBTC hypothesis comes from Betts (1997) and Gera *et al.* (2001) for Canada, Machin (1996) for the UK, De Laine *et al.* (2000) for Australia, and Falk and Koebel (2004) for Germany. Differently from the previous mentioned sector-level analyses, 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 a replacement between skilled and unskilled labour[11]. 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 found that firm R&D and investment in equipment[12] 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. Other US firm-level evidence comes from Dunne and Schmitz (1995), Doms *et al.* (1997) and Siegel (1998) for the Long Island plants. Moreover, the above mentioned 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. Machin (1996), 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 (as it can be seen also by the previous sector-level work by Goux and Maurin (2000)) are not robust as those relating to the

[10] Some of these authors tried to explain the shift in the demand away from unskilled and toward skilled labour not only on the basis of the technological explanations. Berman *et al.* (1994), for example, tried to explain the upskilling through trade and through the military spending due to a defence build-up; however these lasts explanations are not significant. Moreover, Morrison Paul and Siegel (2001) tried to verify simultaneously the effects of technology, trade and outsourcing on the labour structure. Beyond the technology effect, the authors found an important interaction between trade and skilled labour, through computer.

[11] Some authors have analyzed the SBTC hypothesis beyond the national level. Machin and Van Reenen (1998) in their study compared the employment in the US with other six OECD countries (Denmark, France, Germany, Japan, Sweden and the UK) during the Seventies and Eighties and provided evidence that SBTC (measured by R&D intensity) has clear effects of increasing the relative demand for skilled workers. Other important multi-countries contributes are those by Berman and Machin (2000, 2004), while Conte and Vivarelli (2007) discussed the role of technology within globalization: the authors examined the occurrence of Skill-Enhancing Technology Import (SETI) in a sample of 23 low and middle income countries and offered evidence of a capital-skill complementarity that is a fundamental source of the relative skill bias.

[12] Adams (1999) has compared the effects of firm R&D and industry R&D spillovers.

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 division 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). Moreover, an important work for Italy is the one by Casavola *et al.* (1996); the authors demonstrate that wage dispersion does not increase in Italy by the same extent as in the Anglo-Saxon countries[13], furthermore technological progress lead to a significant increase in the employment of white collars[14]. 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[15]. 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. Studies concerning the linkages between the introduction of organizational change (OC) and workers compositions (SBOC) 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

[13] 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].
[14] 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.
[15] 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].

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[16].

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[17]. 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 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, are been recognized to be good explanatory factors of the different skill/unskill ratios showed by firms. In this perspective, established literature has argued for the impact of technological and organizational change on firm occupational structure. Our economic hypothesis is a complementary relationship at the firm level between labour demand and several types of innovations. As discussed above, the utilization of an high number of skilled workers is a

[16] Organizational variables are very difficult to obtain [Vickery and Wurzburg, 1998].
[17] 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.

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, the basic idea is that for firms innovations result profitable if they can count on high competences and capabilities of the workers: only skilled workers are able to give high performances starting from single innovation or clusters of innovations. The literature already analyzed and these considerations suggest us the following main research questions:

1. Are input or 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[18] 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?
4. Finally, given the particular local production systems highly unionized we investigate (see 2.2 that follows), are there some linkages between cooperative aspects of the firm level industrial relations system and the occupational composition?

2.2 Local production systems analysed and the dataset

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 [Brusco *et al.*, 1997]: 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.

[18] 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. Not by chance, in fact, Guidetti and Pini (2006, p. 73) observe that is possible that some training activities, which are aimed on specific and mainly innovative competences, focused on particular classes of workers (skilled), or closely related to the implementation of HPWPs, are classified within HPWPs.

The overall characteristics of the industrial context outlined above sets the two industrial systems within the LPS of Northern Italy [Seravalli, 2001]; they can be considered paradigmatic versions of the so called “Emilian model” [Brusco, 1982; Brusco and Solinas, 1997; 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. On the other hand, however, the importance of its industrial relations system and the strength of the innovative activity distinguish MO and RE from other Emilia-Romagna local production systems. For example, the typical “dense” industrial relations of the area and the participation of workers’ representatives in managerial decisions in the work organization, are indicative of the potentially important role of industrial relations.

Historically, the areas with the strongest industrial structures in Emilia-Romagna since the 1950s have been RE and MO, Bologna in the eastern part of the region, and Parma in the western part, the so called ‘Emilia centrale’ running along the ‘Via Emilia’ route connecting Milan with the Adriatic coast (Rimini) [Bianchi, 1997]. The industrial area of MO and RE has 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 [Aronica, 1998; Bianchi and Gualtieri, 1999]. The LPS are also characterized by the presence of public organizations that provide funding for services, infrastructures, social security, and so on, and contribute to creating a particularly efficient institutional set-up [Becattini and Rullani, 1997; Putnam *et al.*, 1994; Russo, 1986; Seravalli, 2001; Bianchi and Gualtieri, 1999; Ginzburg, 2005]. A fundamental role is played by the presence of strong, well rooted and proactive unions, which shape the industrial system.[19] 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 and Pini, 2004; Antonioli *et al.*, 2004; Antonioli *et al.*, 2007; Antonioli *et al.*, 2010]. It should be remarked that the LPS of MO and RE have recently been interested by some deep changes linked to the globalization process. In some sectors, in particular, such as textiles and clothing, ceramics, and electro-mechanics (the so called “mechatronics”), firms (especially those belonging to industrial groups) have been entering in international networks through joint ventures, financial participations, international outsourcing and delocalization. More precisely, after having gained experience of the Eastern European markets in the previous years, firms are now targeting some other World areas: Latin America, Central Asia and Eastern Asia (China and Indochina) in particular [Murat and Paba, 2005].

[19]This is especially true for the role of CGIL, a traditional confederation with socialist and communist origins. For an overview of the union’s history and the linkages with political parties, see Baglioni (1998).

Our empirical analysis is conducted using a single data set, which results from the match of two surveys[20]. The two surveys involved 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[21]; *(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[22].

Tables A.1a and A.1b evidences the population and the sample used in the empirical analysis. A version of the Cochran test (Cochran, 1977) for the representativeness of the sample shows good results. There exist however some bias. There is an under-representation of the sample respect to the population for the firms with 50-99 employees, mainly due to the minor presence of union representatives within small firms; consequently there is an over-representation of medium firms (100-249 employees), where the presence of union representatives is larger. Moreover there are some minor sector distortions: there is, indeed, an over-representation of non-metallic mineral firms and an under-representation of machinery firms. Anyway 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.

2.3 Methodology

Like other authors [Betts, 1997; Adams, 1999; De Laine *et al.*, 2000; Bratti and Matteucci, 2004; Piva *et al.*, 2005], 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 which exist between innovation activities and respectively White Collars (WC) and Blue Collars (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 estimate[23].

The empirical model is based on the following specification:

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[20] For details of the two surveys and dataset see Antonioli *et al.* (2007) and Lugli and Tugnoli (2008).

[21] 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.

[22] 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.

[23] To this end, see the Breusch-Pagan in notes of the econometric tables.

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

where the dependent variable is the logarithm of the WC and BC workers; i represents each observation; β represents a vector of coefficients, which are related to each vector of independent variables (covariates); α_{WC} and α_{BC} represent the constants of the model and ε represents the error term.

As specified above, the utilization of the two dependent variables allowed by the SUR model is aimed at verifying the statistical association between innovations and industrial relations variables and the different classes of workers.

Among the covariates we can distinguish: firm structural variables, which give information on sector, size, typology, performance, as well as labour contracts (labour flexibility); variables of the industrial relations system; training activities variables; technological innovation variables, which include input (R&D) and output (incremental/radical product/process innovations) of technological process , and also ICT; finally organizational innovation variables.

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 (see table A.3 in Appendix for a detailed description of the explanatory variables).

Finally we underline that frequently in the skill bias empirical literature the innovation variables, especially organizational variables, have been measured as simple dummies variables [Caroli and Van Reenen, 2001; Bauer and Bender, 2004; Piva *et al.* 2005] or even as temporal trend [Betts, 1997]. 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.

3. Results

The results of the econometric exercise are reported in tables 1, 2 and 3.

First, it should be stressed that we settled up different specifications for each synthetic innovation and then we ran a regression with all the innovative indexes (aggregate indexes, table 1). Second, in order to recognize the explicit explanatory variables, we estimated a specification with the main variables used to build the innovation synthetic indexes (specific indexes, table 2). Third, we also ran regressions with multiplicative interaction terms between the different innovation indexes (complementarities, table 3).

Starting from the structural variables, we can see (table 1) that there are some variables which affect both the WC and the BC workers and some others which affect separately the WC or the BC workers[24]. The dummy MORE, which captures the belonging to a particular LPSs[25], is negatively related to the WC while it is positively related to the BC; therefore, although the two LPSs share some common features both in terms of industrial structures and institutional settings, firms located in Modena show a positive linkages with the WC workers while firms located in Reggio Emilia have an industrial context characterized by more BC workers. Concerning the sector variables, the ceramic (NON_METAL) and the textile and clothing (TEXTILE) dummies are significant for both the classes of workers, but they give different results: ceramic firms, in fact, are correlated with more BC workers while for the textile and clothing sector is exactly the opposite (WC). Although the delocalization dummy (DELOC) is never significant we can deduce an important consideration on delocalization through others variables. More than 45% of the textile and clothing firms, in fact, experiences delocalization processes while other sectors have as a whole an average delocalization of 23%. As analyzed before, additionally, the textile and clothing sector results positively related to WC and negatively related to BC workers. All this suggests only for the textile and clothing sector the idea that reorganization subsequent to delocalization leads to an upskilling in the workforce composition [Head and Ries, 2002], and this is even more true if we consider the Outward Processing Trade approach[26] [Helg and Tajoli, 2005].

Differently from these variables, the revenue performance indicator (PROF_REV) and the proportion of turnover made on international markets (FOR_PROF) give significant results only

[24] For brevity we illustrate structural results only in table 1, indeed in the other tables outcomes are substantially identical. Detailed results are available upon request.

[25] MORE is 1 for Modena and 0 for Reggio Emilia.

[26] From the beginning of Nineties the propensity toward the Outward Processing Trade (OTP) has increased particularly in Italy, reaching levels higher than in other European Union countries [Baldone - Sdogati - Tajoli, 2002a] and this is due to the strong specialization Italy has for many traditional productions, which tends to foster this practice. The diffusion of OTP practices in Italian companies (mostly in the textile and clothing industry) has increased so much as to reduce the gap in competitiveness between Italian firms and firms located in countries with low cost of labour [Baldone - Sdogati - Tajoli, 2002b].

toward WC workers. The former, in particular, shows a negative relation, while the second a positive one, underlying the fact that trading with foreign countries involves more skilled workers. Moreover, cooperative firms (COOPF) are sometimes negatively related to BC workers. One of the most significant and important structural variables is the index that measure the trend of flexible labour contracts (TREND_FLC); this variable, in fact, 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[27] 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]. Finally, we maintain size dummies as control variables inside econometric exercise[28].

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 1 and 2). With the first two specifications in tables 1 and 2 (1a, 1b, 2a and 2b) we aim to verify the SBOC hypothesis, while the third and fourth specifications (3a, 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 not emerges 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

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

[28] The robustness of the size dummies as control variable is confirmed by the fact that there is high correlation between large firms (>249 employees) and different types of innovations (tables are available on request). Small firms (in terms of employees) captured by dummies (tab.A.3) are negatively associated with the dependent variables, while the large firms, with more than 499 employees, are positively associated with the dependent variables.

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 with 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 the BC without influencing the 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 2, 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). Several empirical analyses on Anglo-Saxon countries show that technological change has been the main explanatory variable of the occupational structures [Bartel and Lichtenberg, 1987; Dunne *et al.*, 1996 and Machin, 1996], but for the EU continental countries evidence has always been ambiguous [Goux and Maurin, 2000; Mairesse *et al.*, 2001; Piva *et al.*, 2005]. Thanks to the richness of our data we can find that within manufacturing firms of MO and

RE, technological change has an essential role to explain the skill bias; in particular it appears that firms with high index of R&D show also high numbers 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[29] [Acemoglu, 2002]. Summarizing, these results confirm the strong and deep relation between R&D and skills, thus supporting the general skill biased nature of technological change [Nelson and Winter 1982; Dosi, 1988] and, besides, they prove that the relationship between ICT adoption and skills supports the new technological paradigm [Freeman and Soete, 1994; Rifkin, 1995].

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 2.

Now we turn to the outcomes obtained in the several equations analyzed by the synthetic and disaggregated industrial relations variables. We have choose 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[30]. Results are not totally consistent as for the innovative variables, but they are anyway interesting. The synthetic index is not significant, while if we disaggregate it in its components we notice that variables result significant, but only two of them are significant with regularity: the index that measures the interaction between management and union representatives on several items (production, quality, employment, working hours, etc.) (MANUNI_REL) seems to be a good explanatory variable for BC workers (equations 2, 3 and 4); on the other hand, the index that measures industrial relations compared to the preceding year (INDREL_TREND) has a negative relation with BC workers, indicating that a negative trend in

[29] Analysing the origin of the technology-skill complementary, Goldin and Katz (1998) observe that, in the first fifty years of the past century, technology has always been associated with unskill biased: products previously manufactured by artisans started to be replaced by factory and later by interchangeable parts and assembly line [Goldin and Katz, 1998; Acemoglu, 2002].

[30] Antonioli *et al.* (2007) have found that industrial relations show an indirect effects on labour productivity, spurring innovation activities.

industrial relations is experienced in firms with less skilled workers[31]. Thus, we can argue that, across firms, high quality industrial relations are associated more with firms where the amount of BC is high, however, the relations between industrial relations trend and BC is negative. The mixed evidence of the industrial relations aspects on occupational composition does not allow simple interpretations. This first result does not come unexpected [Antonioli *et al.* 2004; Antonioli and Pini, 2004]. Indeed we may argue that local unions have the power that translates into the capacity to make union voice more effective within firms with high BC. 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. Notwithstanding, a negative trend in industrial relations (among unions and management, but also among unions and workers) could be present in firm with low skilled labour, and this explain the second empirical evidence. Surely, additional empirical evidence and maybe more time spanning would be necessary to disentangle this topic.

[31] Only in the first equation we obtain that the index that measures the presence of bargaining (FL_BARG) is weakly and positively significant for the WC while, the index that capture the existence of a bilateral technical commission (BTC) is robustly significant for the BC, obviously with a positive sign.

TABLE 1 – *Results of the econometric exercise (SUR estimates) with innovative synthetic indexes*

	TRAINING		ORGANIZATION		TECHNOLOGY		ICT		ALL	
	1a	1b	2a	2b	3a	3b	4a	4b	5a	5b
	lnWC	lnBC	lnWC	lnBC	lnWC	lnBC	lnWC	lnBC	lnWC	lnBC
SIZE DUMMIES	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
MORE	(-) **	***		**	(-) **	***		***	(-)*	**
NON_METAL	(-) *	**	(-) *	**	(-) **	***	(-) *	***		*
TEXTILE	***	(-) **	***	(-) *	***	(-) **	***	(-) *	***	(-) *
COOPF				(-) *						(-) *
PERF_REV	(-) *		(-) *		(-) **		(-) **		(-) **	
FOR_PROF	**		**		**		**		**	
DELOC										
TREND_ FCL	**	(-) **	**	(-) **	*	(-) *	**	(-) *	***	(-) ***
TRAIN	**		-	-	-	-	-	-	*	
ORG	-	-		(-) ***	-	-	-	-		(-) **
TECH	-	-	-	-	**		-	-		
ICT	-	-	-	-	-	-	**		**	
IND_REL										
_CONS	***	***	***	***	***	***	***	***	***	***
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; 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 2 – *Results of the econometric exercise (SUR estimates) with innovative specific indexes*

	TRAINING		ORGANIZATION		TECHNOLOGY		ICT		ALL	
	1a	1b	2a	2b	3a	3b	4a	4b	5a	5b
	lnWC	lnBC	lnWC	lnBC	lnWC	lnBC	lnWC	lnBC	lnWC	lnBC
STRUCTURAL VARIABLES (size, sector, LPSs, typology, labour contracts (labour flexibility), performance etc.)										
Industrial Relations										
MANUNI_REL				**		**		**		
BTC		***								**
FL_BARG	*									
INDREL_TREND	(-)**	(-)**		(-)**		(-)**		(-)**	(-)**	(-)*
Training										
TRAIN_ADV			-	-	-	-	-	-		
TRAIN_RATIO	**		-	-	-	-	-	-	*	
TRAIN_COMP	*	(-)*	-	-	-	-	-	-	*	(-)**
Organizational Innovation										
OUTSORC	-	-			-	-	-	-		(-)**
INSORC	-	-			-	-	-	-		
FIRM_REL	-	-		(-)*	-	-	-	-		
ORG_PROD	-	-			-	-	-	-	(-)*	
ORG_LAB	-	-	***		-	-	-	-		
REW_TOT	-	-			-	-	-	-		
Technological Innovation										
TECH_INP	-	-	-	-	***		-	-	**	
TECH_OUT	-	-	-	-			-	-		
ICT										
ICT_PROD	-	-	-	-	-	-				
ICT_COM	-	-	-	-	-	-				
ICT_MAN	-	-	-	-	-	-	*		**	
_CONS	***	***	***	***	***	***	***	***		
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; 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 pointed out above, 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 3. 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* are not opposite [Black *et al.*, 2003], on the contrary they show together a 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 rapid and continuing decline in the cost of technologies and the diffusion of computer are a powerful change in the environment of the firm; therefore, new technologies have altered the structure of the organization: changes in hierarchical relationship, decentralization of decisions, shift in the task content of different groups of workers, changes in reward schemes, etc. [Bresnahan et al., 2002]. It emerges that pervasive technological progress and new organizational practices of the last decades are not events totally unrelated to each other (SBTC+SBOC) [Aghion *et al.*, 1999; Bresnahan *et al.*, 2002]. Some authors, in particular, point out super-additive effects which come out from technological and organizational changes and translate in firm's performance, measured either in terms of productivity or profitability [Pavitt *et al.*, 1989; Milgrom and Roberts, 1990; Black and Lynch, 2001].

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 3 – *Results of the econometric exercise (SUR estimates) with innovative interaction terms*

	TRAIN*ORG		TRAIN*TECH		TRAIN*ICT		ORG*TECH		ORG*ICT		TECH*ICT	
	1a lnWC	1b lnBC	2a lnWC	2b lnBC	3a lnWC	3b lnBC	4a lnWC	4b lnBC	5a lnWC	5b lnBC	6a lnWC	6b lnBC
STRUCTURAL VARIABLES (size, sector, LPSs, typology, labour contracts (labour flexibility), performance etc.)… …and industrial relations synthetic variable												
TRAIN*ORG	***	(-) **	-	-	-	-	-	-	-	-	-	-
TRAIN*TECH	-	-	***		-	-	-	-	-	-	-	-
TRAIN*ICT	-	-	-	-	***		-	-	-	-	-	-
ORG*TECH	-	-	-	-	-	-	*	(-) **	-	-	-	-
ORG*ICT	-	-	-	-	-	-	-	-	**	(-) *	-	-
TECH*ICT	-	-	-	-	-	-	-	-	-	-	**	
_CONS	***	***	***	***	***	***	***	***	***	***	***	***
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; all the five regression 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 in terms of 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 the technological and organizational change a robust explanation for the upskilling phenomenon. For Anglo-Saxon countries the technological explanation is the prevalent, while for continental European countries some studies point out to the organizational explanation, which sometimes shows a negative effect on the less skilled workers rather than a positive one on the skilled. Several authors evidence also the existence of key complementary relations between innovative variables.

Hence, the present paper aims to provide 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.

Using survey data collected for two local production systems concerning about 250 firms, we obtain interesting results.

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 interpretation; 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	Logarithms of the number of White Collar (WC) workers within the local unit	*0*	*6,93*	*3,60*
lnBC	Logarithms of the number of Blue Collar (BC) workers within the local unit	*0*	*7,52*	*4,42*
	Controls and Explanatory Variables			
	Structural Variables			
Local Production System Dummy	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	*0*	*100*	*45,04*
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*
	Structural Variables (flexibility)			
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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