ARGUMENTA OECONOMICA
No 1-2 (19) 2007
PL ISSN 1233-5835

Giuseppe Calzoni *, *Cristiano Perugini* *, *Fabrizio Pompei* *

SKILL-BIASED EFFECT OF TECHNOLOGICAL CHANGE AND INCOME INEQUALITY: A CROSS COUNTRY ANALYSIS

The introduction of new technologies and organisational changes produces direct effects not only on the demand for skilled workers, at the expense of unskilled ones, but also on the upward wage dynamics of the former and on the wage decline of the latter. Depending on various social, economic and structural factors, the exacerbation of wage disparities may in turn produce effects on income re-distribution, as evidenced by extensive literature. In this paper, we propose a theoretical and empirical analysis in two connected steps. The first aims at investigating theoretically and empirically the changes in labour demand produced, among other factors, by the introduction of new technologies. In the second step, information about qualitative evolution of labour demand is examined, among other traditional determinants, as a factor affecting income distribution. The empirical analysis is carried out for a set of eastern and western EU countries.

Keywords: technological change, skill-biases effect, income distribution
JEL classification: O33, J24, D31, O15

1. INTRODUCTION

The extensive existing literature on income inequality has focused on the role of the labour market from various perspectives. One of them is the influence of the introduction of innovations in labour markets, particularly on qualitative and quantitative aspects of labour demand, and on wages and productivity dynamics, in sectors of differing technology intensity. Our approach is essentially explorative, and aims at shedding light on the complex relationships between technological change, quantitative and qualitative labour demand dynamics, and income distribution. For this aim, we first present the theoretical framework of the paper, supported by a review of the theoretical and empirical literature on the topics of interest (section 2). In the following empirical part of the paper (section 3), we first describe the dataset employed to test empirically, for a set of eastern and western EU countries, the validity of our scheme of interpretation. After

* Department of Economics, Finance and Statistics, University of Perugia, Italy

having provided some basic descriptive analysis (§ 3.1), we describe the econometric approach adopted (§ 3.2) and the results obtained (§ 3.3). Section 4 summarizes the results and concludes.

2. THEORETICAL FRAMEWORK AND LITERATURE REVIEW

The empirical and theoretical literature regarding the inequality of income distribution is ample and well articulated (Slottie and Raj, 1998), and an important part of it is composed of contributions identifying the determining factors connected to the effects on labour markets of technological change. We focus here on changes occurring in the qualitative composition of labour demand and on its impact on the distributive patterns of developed and transition economies. Our theoretical (and, consistently, empirical) approach is thus composed of two connected steps (Figure 1).

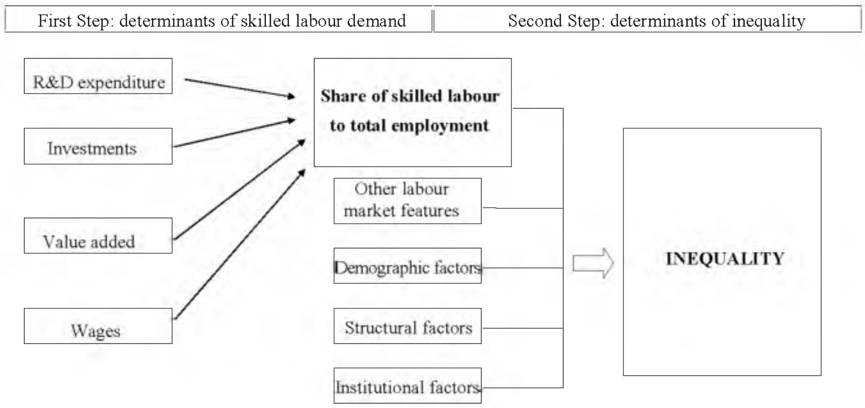

Figure 1. Technological change, labour market and income inequality: a two-step analysis

Source: authors' elaboration

The first step aims at depicting the effects produced by technological change on the relative share of high-skill labour demand: the related theoretical background is reviewed in section 2.1. Then we place the effects of qualitative labour demand dynamics among the determinants of income inequality, as traditionally identified in the literature. These aspects are discussed, without any claim of exhaustiveness, in section 2.2.

2.1. Technological Change and Labour Demand Dynamics

Many authors argue that, since the 1980s, the new technological wave has caused a considerable increase in the share of skilled labour in the total labour force, over time and among industrialized countries (Wood, 1995; Mishel and Bernstein, 1998; Berman et al., 1994; Machin and Van Reenen, 1998, Aghion and Howitt, 2002¸ Piva et al., 2005).

However, it is worth noting that this Skill-Biased Technological Change (SBTC) hypothesis is mainly supported by the skill-complementary character of many technologies of recent years (Redding, 1996; Acemoglu, 1998; Piva et al., 2005), in contrast with the dominant skill-replacing innovations of the nineteenth and twentieth centuries, when the transition from the artisan-based to factory-based system of production (Marx, 1961) and the subsequent massive introduction of Tayloristic methods (Braverman, 1974; Goldin and Katz, 1998) have been at work.

On the theoretical level, Acemoglu (1998) has shown that skill-complementary technologies are the outcome of a process of choice and contribute towards defining a specific direction of technological change, even though the driving forces of this process can very often be considered only partially endogenous. Thus, the striking supply of skilled labour in the US during the 1970s, due to the increased number of college graduates, was probably motivated not only by the economic expectations of those students. In any case, this increase in the supply of skilled labour first moved the economy along the short-run (downward-sloping) relative demand curve and reduced the skill premium (i.e., the difference between earnings by college and high school graduates) in the same years. But later (1980s and 1990s), an increase in the magnitude of the market for complementary–skill technologies occurred, and a direct technological effect shifted the relative demand curve upwards, which in turn made both the demand for skilled labour and the skill premium to rise above their original levels (Acemoglu, 1998, p.1057).

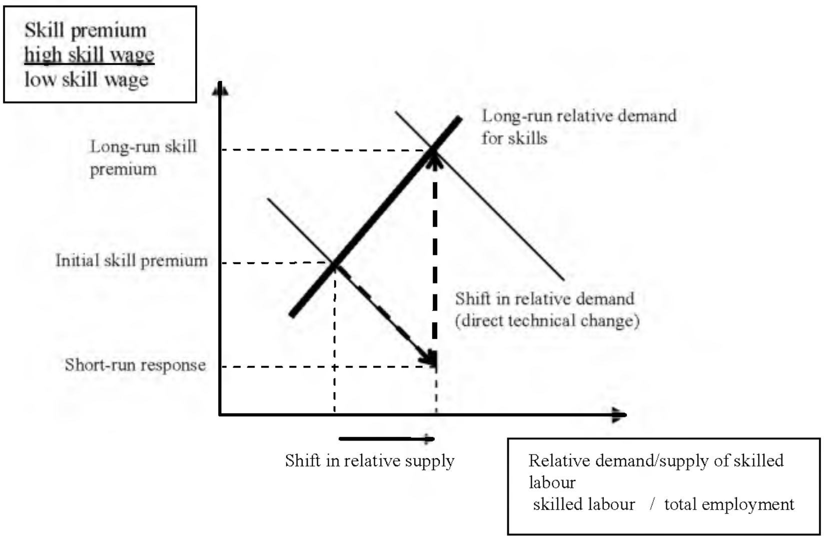

Figure 2. SBTC and dynamics of wage inequality

Source: Acemoglu (1998)

Of course, this mechanism regards each sector and, depending on many economic and structural factors, the relative share of high-skill labour may be different in the various sectors at a given point in time. So the effects on overall income inequality are the result of the complex composition of single sector situations.

The part of this paper on testing the SBTC hypothesis in European countries for recent years relies mainly on the above-mentioned theoretical considerations, but also moves from the previous findings provided by the empirical literature.

First of all, there is important international evidence concerning the significantly pervasive role played by SBTC in the shift of skilled labour demand in developed countries (Berman et al., 1994). According to these authors, the substitution towards skilled labour within industries occurred in ten OECD countries, and the same manufacturing industries that substituted towards skilled labour in the United States in the 1980s also did so in the other developed countries. Thus, the pervasiveness of SBTC is the main explanation of the phenomenon although, according to the Heckesher-Ohlin model, international trade also played a role in increasing the relative demand for skills. Remaining at the cross-country level of analysis, other authors have stressed the importance of a directly observable indicator of technology, such as R&D intensity, in explaining the degree of skill upgrading (Machin and Van Reenen, 1998). In this case, the non-production wage-bill share equation (in which the dependent variable measures the incidence of non-production/white-collar wages to total) is derived from a trans-log function cost. Therefore, the key explanatory variable, R&D intensity, appears on the right side of the equation, among the more traditional determinants of labour demand (value added, capital and wages).

It is worth noting that in the above two studies only manufacturing sectors were taken into account, and that the distinction between non-production/production workers in capturing high/low skills respectively was deemed problematic by the same authors.

A significant step forward in the direction of an improvement in the statistics used was made by Gera et al. (2001). In this case, the effect of technical change on the relative demand for skilled workers was analysed only in the Canadian economy, but both industrial and service sectors were examined, even though this distinction was not significant in the end. The same authors paid more attention to identifying the skill level of workers, using various supplements of the monthly Labour Force Survey. However, the real interest in this study lies in the observable indicators of technology, which extend the traditional econometric model with the trans-log cost function. Indeed, besides R&D intensity and the stock of patents, a proxy of technology embodied in capital goods was considered by introducing the age of capital. The basic idea was that new capital is more productive than older capital, because it is more likely to embody best-practice technologies (Wolff, 1995; Gera et al. 1998). Eventually, the findings of the empirical analysis of Gera et al. (2001) show the significant explicative power of the age of capital, which is inversely related to the relative demand for skilled labour.

2.2. Structural, Socio-demographic, Economic and Institutional Determinants of Income Inequality

Some structural features of economic systems are key determinants in various distributive patterns, and these long-term and persisting attributes are used to support evidence of significant differences recorded among countries and reduced dynamics within them (Li et al., 1998). Consistent with the aims of this paper, we first consider the role attached to human capital endowments and then review the other determinants identified in the literature.

A first important channel connected with human capital has already been described in section 2.1. The SBTC hypothesis states that higher skill premia, stemming from greater qualified labour demand, affect wage inequality in the labour market. For this reason SBTC is seen as playing a crucial role in understanding poverty, social stratification and economic incentives facing workers, given that, particularly in countries that lack compensatory government policies, labour market inequality may contribute as a major determinant of disparities in living standards (Blau and Kahn, 1996).

In the literature on economic inequality, these aspects are often related to the degree of openness of economic systems (Barro, 2000; Li et al., 1998; Richardson, 1995), and to technological change which encourages specific segments of labour demand. According to the standard theory of international trade, country specialization depends on the different endowments of productive factors. In particular, in a context rich in human and physical capital (typically in better-off countries) which experiences competitive advantages in capital and technology-intensive production, an increase in international trade tends to foster high-skill labour demand, reducing the relative wages of low-skilled workers. Stronger international competition also supports this trend, since it accelerates the rates at which new technologies are adopted, demanding human capital and crowding out low-skilled labour (Kim, 1997). In addition, this gap may tend to increase, since domestic demand is more oriented towards high technology or differentiated products, which require higher knowledge intensity (Wood, 1995). These dynamics may foster income inequality at least until the share of high-skilled labour (high relative wages) does not reach a critical threshold, beyond which income inequality may decrease. The opposite dynamic occurs in countries (typically, developing countries) which have a high incidence of unskilled labour, where inward capital migration flows and increased export opportunities for low-skill, labour-intensive products tend to increase the employment level as well as the relative wages of the worse-off labour force, thus reducing disparities. However, this interpretation tends to conflict with much empirical evidence and with widespread opinions about the distributive consequences of the processes of globalization (Barro, 2000). These seem to favour the richest social classes (those able to take better advantage of the new opportunities offered by larger markets) and so, especially in the poorest countries, to encourage inequality. The relationship between trade, growth and poverty is also the focus of the important paper by Dollar and Kraay (2004), who claim that trade liberalization leads to a higher growth of average incomes and that the incomes of the poor increase proportionately.

Beyond these aspects, human capital endowments may play a crucial role in determining income distribution, for other important reasons. On one hand, for example, Panizza (2002) and Barro (2000) associate low levels of human capital with a reduced capacity to gain access to job positions (or to use technological developments) which would guarantee better income opportunities, especially in contexts where technological progress demands highly skilled labour and thus tends to widen wage gaps. On the other hand, in other authors' view, it is the distribution of human capital, rather than its average level, which gives access to different options for work positions, and is crucial in explaining inequality structures (Partridge et al., 1996). From this labour-supply point of view, an important role may be played by the existence of credit constraints. These credit market imperfections may indeed weaken the ability of the worse-off population to make those investments (i.e., human capital) which could promote higher income opportunities (Li et al., 1998). Similarly, the degree of evolution in financial markets in general and access to more sophisticated tools can also encourage more equitable distributive structures (Greenwood and Jovanovic, 1990).

Further explanations connected with human capital endowment have a more specific political economy basis, and associate the low levels of human capital of the "poor majority" with a reduced capacity to limit the lobbying capacities of the "rich minority" which tends to impose anti-distributive policies (Li et al., 1998). Again, from a political economy viewpoint, the degree of democratization of a country (existence of civil liberties) is a crucial factor, since it imposes important constraints on the richest share of the population, weakening its conservative pressures. Similarly, a growing degree of democracy (electoral rights) and a stronger rule of law are considered by Barro (2000) to be factors that encourage a more equal income distribution.

Many other potential determinants of income distribution patterns are also considered explicitly.

First, the level of per capita income assumes prominent empirical and theoretical importance in the inverted U-shape of the Kuznets curve (and its evolutions) (Kuznets, 1955; Robinson, 1976). This indicator represents the degree of development and of structural diversities in cross-country or inter-temporal comparisons. In the context of a developing economy, the level of development is often proxied with the geographic distribution of the population, particularly with the degree of urbanization of a country (Li et al., 1998; Panizza, 2002; Partridge et al., 1996). This is indeed intended primarily as the identification/contraposition between the rural/agricultural and urban/industrial (or tertiary) worlds, as in the case of the original Kuznets curves and their most recent versions (Barro, 2000). As reported by Barro (2000), some recent versions of the Kuznets curves refer rather than to the shift from the agricultural to the industrial sector to the evolution between an unsophisticated financial sector and a modern financial industry (see, for example, Greenwood and Jovanovic, 1990). Alternatively, they identify the two sectors on the basis of technology regimes (Barro, 2000). If the development process is represented as the evolution from a rural, farming-based society towards an urban/industrial one, the initial reduced level of inequality may be explained by some characteristics of the first stage of development and, most markedly, by a level of per capita income which is essentially low but significantly homogeneous, except for the incomes of the rich urban minority. When, in a later stage of development, migration from the countryside intensifies, the share of the richer population living in urban/industrial areas increases, and this induces a more marked inequality within the whole system (this trend corresponds to the increasing part of the Kuznets curve). This income differential (and the development process itself) fosters further movement of workers towards urban centres, which now account for the majority of the population which receives relatively high wages. At the same time, in the rural sector, the relative shortage of labour tends to push salaries upwards. The joint effect of these two forces leads to an increase in distributive equity (the downward part of the Kuznets curve). To summarize, when the degree of urbanization (expressed in terms of the population living in urban areas or as the non-agricultural population) increases, economic inequality grows (developing countries); beyond a given threshold (in developed, i.e., industrialized or service-based countries) economic inequality starts to decrease. The arguments provided by the supporters of the Kuznets curve explanation also provide ground for a discussion of the effects of economic growth rates on income distribution. This is one of the most debated aspects in the literature, not only because the distributive effects of economic growth are ambiguous, but also because the causal direction is uncertain (Kim, 1997). We do not enter into details of this debate here; however, reviews of papers dealing with these aspects are available in Bénabou (1996), Bertola (1999) and Aghion et. al. (1999).

Another set of explanatory factors is associated with demographic features (and their consequences in labour markets), such as the age structure of the population (Panizza, 2002; Partridge et al., 1996) or its degree of heterogeneity (ethnic, linguistic or religious) (Barro, 2000; Mauro, 1995). For example, in very diversified contexts, more pronounced income inequality is to be expected due to the fact that these contexts are the outcome of substantial in-migration flows which tend to drive the wages of low-skilled workers downwards (Topel, 1994). A similar effect (pressures on low-skilled labour and increase in inequality) is generated when women participate highly in the labour market (Topel, 1994), although some alternative interpretations suggest that the entrance of women into the labour market, favouring integration of household incomes, acts as a factor reducing inequality (Bradbury, 1990, in Partridge et al., 1996). High labour market participation (linked to the slight presence of discouraged workers) should favour higher equality; the same should happen with regard to the average age of the labour force (as a proxy of informal human capital endowment). Lastly, among the institutional features of the labour market, the degree of unionization and centralized bargaining should create more homogeneous wage level distributions (Partridge et al., 1996).

Again, from an institutional point of view, the role of social security systems is also often emphasized by assessing the impact on distributive patterns of differing social security arrangements (e.g., Esping-Andersen, 1990; Korpi and Palme, 1998; Castles and Mitchell, 1992), although the inverse causal direction of the relationship is debated. For example, for Persson and Tabellini (1994), one of the reasons why inequality negatively affects economic growth rates is that it entails larger social transfers. A more generous social system is usually expected to reduce inequality: however, some contributions show how the inverse relationship may prevail (e.g., Tullock, 1997), due to the fact that limited budget increases benefit efficiency, the transfers being better directed only to those actually in need. Other studies (e.g., Holsch and Kraus, 2002) beyond the size of social security systems, consider the impact of some of their features (e.g., centralization, coverage and duration of benefits).

3. EMPIRICAL ANALYSIS

3.1. Data, Variables and Descriptive Analysis

As discussed in the previous sections, the first step of an analysis concerning testing the SBTC hypothesis needs a reliable indicator of skilled labour demand on the left side of the equation. Identification of white-collars with skilled workers and blue-collars with unskilled ones is quite common in the literature, but not completely exhaustive. Actually, the white-collar category very often includes subsets of unqualified workers, such as a certain type of clerical personnel, whereas highly qualified manual workers are classified as unskilled labour because they are not provided with a formal tertiary level of education. For these reasons, we used recent statistics released by Eurostat concerning Human Resources in Science and Technology (HRST) (Eurostat, on-line statistics). The "occupation" subset of HRST, used in this paper, includes the following categories of workers:

- professionals, i.e., workers whose main tasks require a high level of professional knowledge and experience in the fields of physical and life sciences, or social sciences and humanities;
- technicians and associate professionals, i.e., workers whose main tasks require technical knowledge and experience in one or more fields of physical and life sciences, or social sciences and humanities.

These types of occupations typically require successfully completed education at the third level, corresponding to the International Standard Classification Education (ISCED) levels 6, 5a and 5b. However, whether the people involved have or do not have this formal education (e.g. they have formal education below ISCED class 5b) is irrelevant, as those in these occupations are automatically considered as belonging to HRST. Therefore, the advantage of using this Eurostat classification consists of capturing the tacit knowledge of highly qualified and experencied blue-collar workers occupied in complex tasks, and of considering them as provided with informal education as skilled labour.

As regards the determinants of skilled labour demand, we focused on business expenditure in research and development, investments, remuneration of labour and added value.

R&D expenditure is also provided by Eurostat, which endorses generally comparable data at country level and good breakdowns at sectoral level. R&D is of course an innovative input, which does not perfectly describe the occurrence of new technology. However, according to Machin and Van Reenen (1998, p. 1218), no single proxy for technology is perfect. Despite these drawbacks, there is a long line of research establishing that R&D expenditure is a reasonable proxy of innovative processes (Griliches et al., 1991). It is also worth noting that most R&D investments are destined for the remuneration of professionals and technicians involved in it. So that, in the field of SBTC studies, this indicator seems more suitable to proxy skill-complementary technologies.

The other explanatory variables were all drawn from the Cambridge Econometrics database.

The *investments* variable is a proxy for overall new technologies embodied in new capital. According to Acemoglu (1998), technologies are skill-complementary not by nature, but by design. Therefore, there are driving forces, partially shaped by the economic behaviour of agents, that trigger the demand for different kinds of labour. If the size of the market of skill-complementary technologies (R&D expenditure) is the main driving force of skilled labour demand, there may also be counter-forces shaped by skill-replacing technologies which inhibit the demand for skilled labour. The overall technologies included in investments could play this role.

As regards the remuneration of labour and added value, it is sufficient to state that they are the traditional factors included in the standard labour demand model (Bartel and Lichtenberg, 1987; Berman et al., 1994; Machin and Van Reenen, 1998; Piva et al., 2005). Thus, in our approach, they play the role of control variables.

Eventually, all the variables of the first relationship estimated were normalized by the number of employees at sectoral and country levels. Consequently, we regress the *share of HRST to total employment* (skilled labour demand) to *per capita R&D expenditure*, *per capita investments*, *per capita added value*, and *average wage* of the sector in a given country.

The particular dependent variable used in the first step of the analysis led us to select a sub-sample of 14 European Union member countries, due to the lack of data: these are ten western members (Belgium, France, Italy, Greece, Germany, UK, Spain, The Netherlands, Ireland, Portugal) and four new members (Poland, Hungary, Czech Republic, Slovenia).

We also aggregated some sectors in order to match the dependent variable and its covariates, and obtained the 8 macro-sectors listed in table 1. This arrangement is not only for mere statistical reasons. For example, the distinction of manufacturing into *hi-tech*, *medium-tech* and *low-tech* is functional to verifying whether SBTC is an exclusive phenomenon concerning emergent and dynamic industries, or whether it can also extend to more mature production contexts, like *medium* and *low-tech* sectors.

Table 1

Macro-sectors and corresponding Cambridge Database sectors

Macro-sectors	**Primary & Construction**	**Hi-Tech Manufacturing**	**Medium-Tech Manufacturing**	**Low-Tech Manufacturing**
Cambridge econometric database sectors	Agriculture Mining and energy supply Construction	Electronics	Fuels & Chemicals Transport Equipment Other Manufacturing	Food Textiles
Macro-sectors	**Financial & Other market services**	**Communications and Transport**	**Wholesale**	**Non Market services**
Cambridge econometric database sectors	Financial Other market services	Communications and Transport	Wholesale Hotels and Restaurants	Non Market Services

Source: authors' elaboration

We believe it is now interesting to show the evolution of skilled labour demand (proxied in our case by the share of HRST in total employment) over a time interval longer than that used in the econometric analysis (1994-2004).

Diagrams 1 and 2 plot skilled labour demand in the 14 EU countries, divided into two groups in order to make the graphics clearer. Two benchmarks, *sample average* and *EU-25 average*, were taken into account. The different length of the lines is due to lack of data.

As regards the older and chief EU members, diagram 1 displays an overall increase in the share of HRST over total occupation, although Spain and the UK remain below both sample and EU-25 averages. For Italy, a sort of *catching-up* process seems to be working, because this country exceeded the sample average in 2000 (23%) and touched the EU-25 average in 2004 (26%). A very similar fast growth is also reached by Spain, but this country started with lower original levels of qualified human resources, whereas the UK shows a very slow growth of skilled workers and a divergent path.

The comparative situation of the UK and Italy is quite controversial, because in the same period the former maintained twice the level of R&D expenditure over GDP with respect to the latter (especially in the business sector: 1.2% *versus* 0.5%) and, although the labour productivity per hour worked is below the EU-15 average, the value of this indicator increased for the UK but it decreased for Italy (Eurostat, 2007).

In the remaining four countries of diagram 1, The Netherlands, Germany, Belgium and France, the evolution of skilled labour demand showed levels above the EU-25 average (26%). The position of these countries seems, at first sight, to be more coherent with the view of the current paper: higher levels of skilled labour demand are motivated by higher R&D expenditure and, between 1995 and 2004, probably caused the higher levels of labour productivity per hour worked detected by Eurostat (2007).

In the second group of EU members, we find the same overall increasing trend of the first, but only two eastern countries show HRST proportions above the benchmarks: Slovenia and The Czech Republic, which reached levels very close to that of German in recent years (diagram 2).

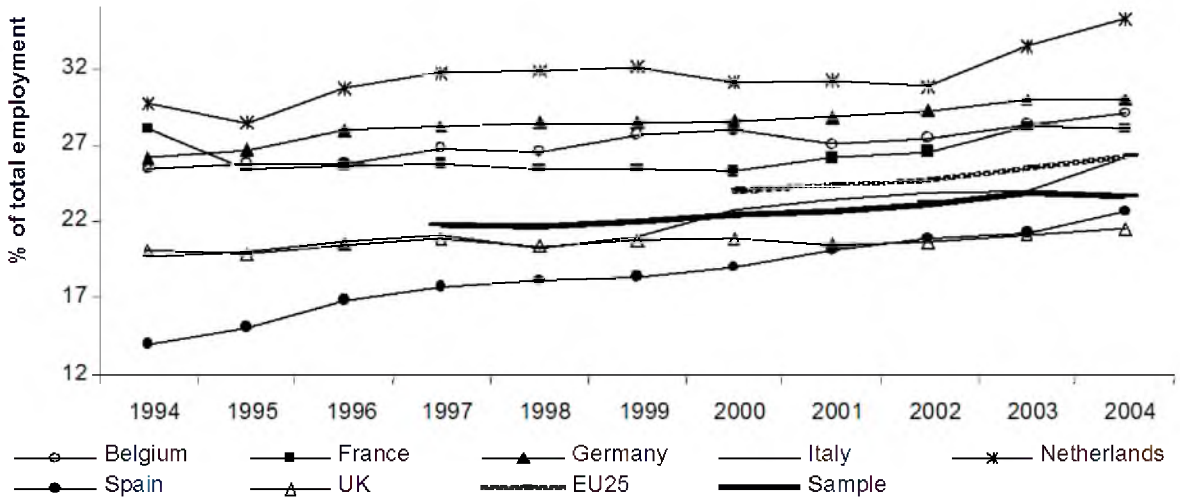

Diagram 1. Skilled labour demand in EU countries (group 1).

Source: authors' elaboration

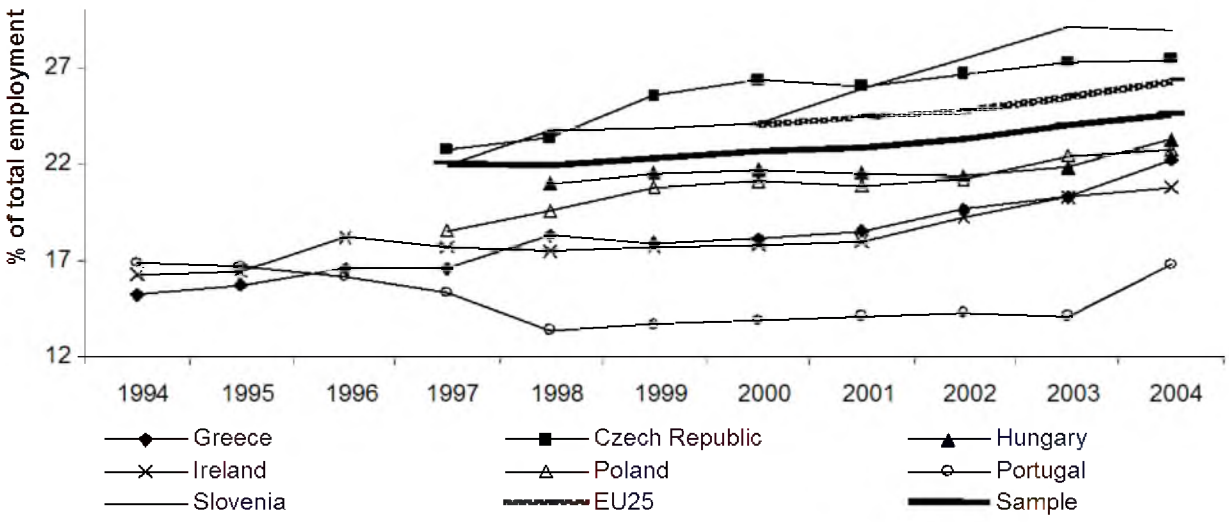

Diagram 2. Skilled labour demand in EU countries under study (group 2)

Source: authors' elaboration

Poland and Hungary share a very similar increasing trend, although they do not reach the sample and EU-25 averages. Below them, Greece and Ireland also demonstrate a positive growth path – unlike Portugal, where the skilled labour market declined notably between 1994 and 2003.

When we analyse skilled labour demand by sectors, we observe a similar overall increasing trend (diagram 3). It is not surprising that the major proportion of HRST is located in non-market services, in which public administration, education activities embodying universities and other public institutions of scientific research, health and social work are examined.

In the other sectors, it is worth noting that financial services is the only sector that shows levels of skilled labour above the sample average. Indeed, within this macrosector, we find advanced business services and specialized market R&D services, besides banking and financial intermediation.

The fast growth of HRST in both medium and low-tech sectors, which allowed the latter to reach the levels of hi-tech industries in the last few years is quite interesting. This is probably the consequence of the increasing importance of highly qualified and experienced workers with tacit knowledge, gained in the mature industries of countries like Italy and Germany (Eurostat, 2007).

The primary sector, which also includes mining, energy supply and construction, ranks bottom with traditional wholesale activities, in which the fraction of human capital does not exceed 10% of total employment.

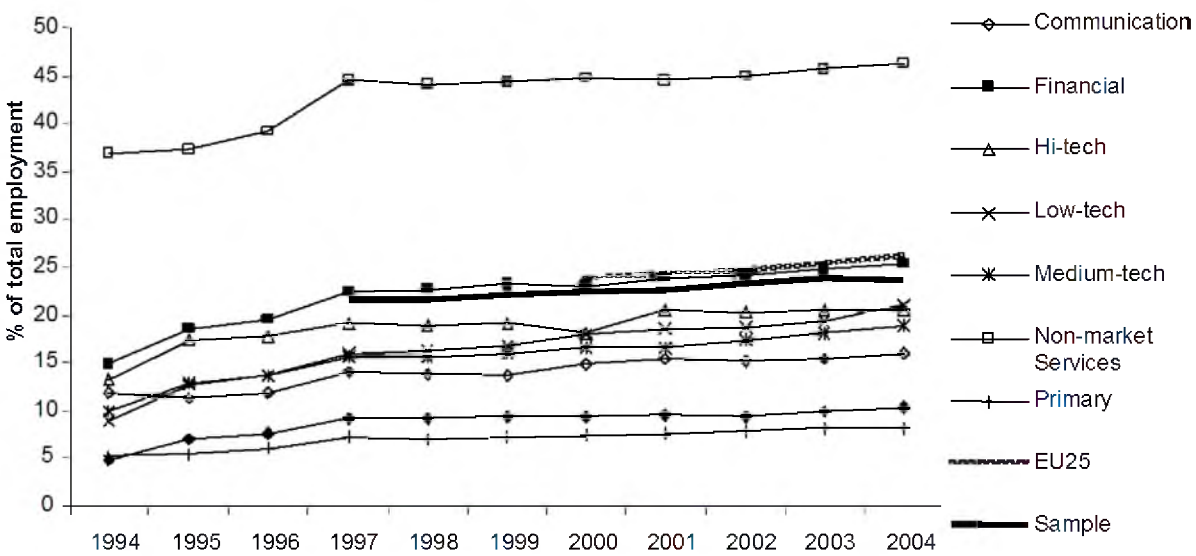

Diagram 3. Skilled labour demand by macro-sectors.

Source: authors' elaboration

As for information about inequality levels, the data is drawn from the World Income Inequality Database (WIID), version 2.0a-June 2005, provided by the United Nations University – World Institute for Development Economics Research (UNU-WIDER). (The database and user guide are available at: http://www.wider.unu.edu/wiid/wiid.htm.) This database collects and processes inequality measures calculated by various national and international institutions. According to the availability of data about the labour market, we were able to assemble a panel database covering 14 countries for the years 1995-2001. Like the countries of the old EU (before the 2004 Eastern enlargement), data is drawn from the Eurostat on-line database; data for the four central and eastern new EU members are from the TransMONEE database (2004), provided by UNICEF International Child Development Centre in Florence. With the only exception of the Czech Republic, all the data share common features: the inequality index considered is the Gini coefficient based on disposable income, calculated using the household as the statistical unit, weighting the data by means of person weight and employing a household equivalence scale. In the case of the Czech Republic, the Gini coefficient was computed using household weights and no equivalence scale. All the labour market, demographic and economic indicators are drawn from the Eurostat on-line database. The indicators are: Employment rate (ER), Female employment rate (FER), 15-24 years employment rate (Young ER), 55-64 years employment rate (Old ER), Long-term unemployment rate (long UR), part-time share of total employment (Part-time share); share of temporary contracts on total employees (Temporary share), share of population aged 65 and more (Old pop share), population density (Dens), per capita GDP (p capita GDP), and expenditure on social protection benefits as a percentage of GDP (Welf). The industry composition of employment data is from Cambridge Econometrics Ltd. The labour market institutional variables are drawn from the OECD employment outlook 2004. The variable used are: Bargaining centralization (Centr) and Union density (Union), which are not available yearly. So, the data closest to the 1995-2001 period have been used.

Table 2 lists some basic descriptive statistics of inequality levels in the EU countries considered. The average inequality level decreased by more than one point during 1995-2001. Similarly, the differences among the countries tended to fall. This is illustrated by the decreasing trend of the coefficient of variation and by the reduction of the differences between the maximum and minimum values (see also box plots in diagram 4).

Table 2

Descriptive analysis of inequality levels (Gini coefficient)

	1995	1996	1997	1998	1999	2000	2001
Mean	30.40	30.16	29.65	29.30	29.43	28.99	29.04
Median	30.85	30.85	30.20	29.95	29.85	29.70	29.05
Maximum	37.40	36.80	37.40	38.00	36.40	34.70	37.10
Minimum	21.60	23.00	23.90	21.20	23.20	23.10	23.70
Coeff. of variation	0.64	0.55	0.73	0.82	0.57	0.49	0.52

Source: authors' elaboration

If we look at the single countries, in 1995 Portugal, Ireland, Greece, Italy, Poland and the UK showed a Gini coefficient above 30, while the Czech Republic, Hungary and Slovenia and Germany were at the lowest levels. Six years later (in 2001) the "club" of the top countries remained unchanged with the exception of Italy (which fell to below 30), whereas the countries at the bottom of the distribution recorded remarkable increases in their inequality levels (with the exceptions of Germany and Slovenia). The shape of the distribution in 2001 (represented by means of a kernel density distribution) is not too far from a normal density distribution.

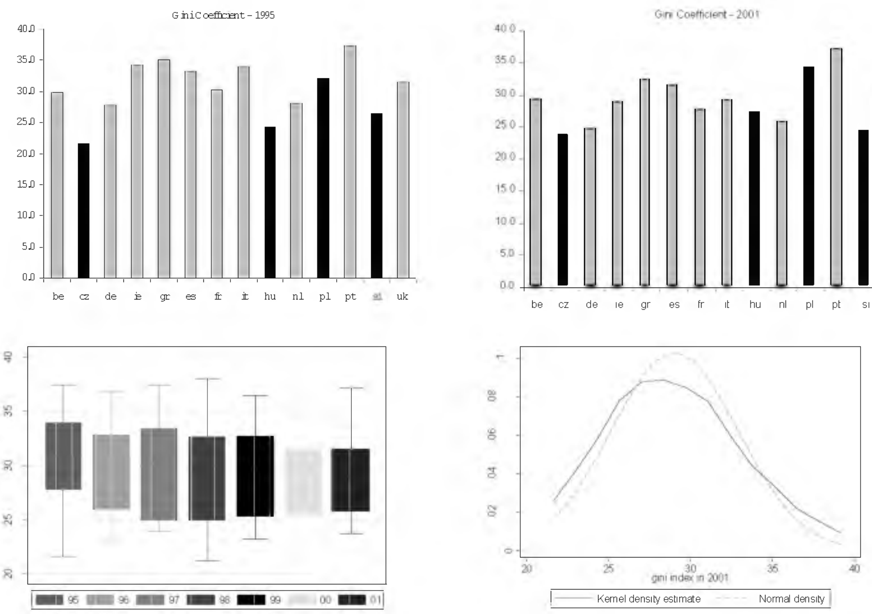

Diagram 4. Inequality in European countries

Source: authors' elaboration

Diagram 5 provides a set of scatter diagrams in which the Gini coefficient is plotted against various economic and labour market variables, and provides evidence of a few interesting relationships. An example is the case of per capita GDP, in which the inverted U-shape explained by Kuznets is clearly identifiable. An opposed interpolation line can be drawn for the relationship between inequality and the share of population aged 65 years and over. The remaining diagrams highlight only weak relationships between the female employment rate (negative correlation coefficient of 0.38), employment rate of people aged 55-64 years (positive correlation of 0.45) and union density (negative coefficient of 0.53).

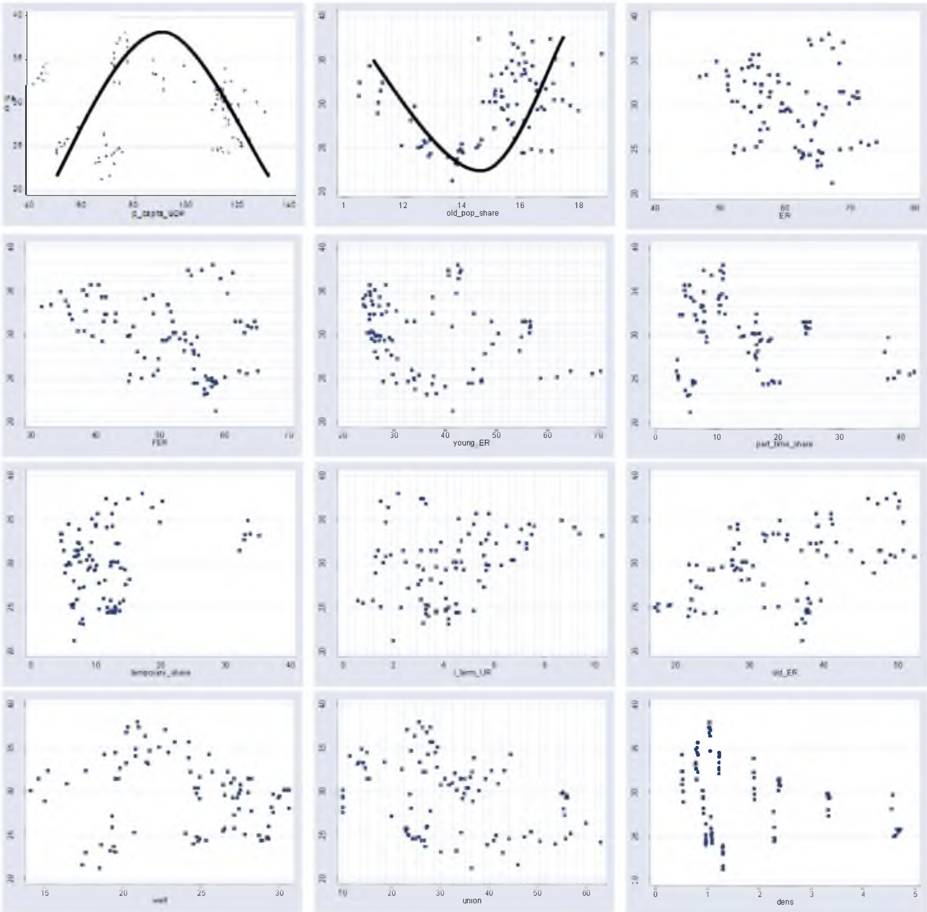

Diagram 5. Inequality measures versus economic, demographic and labour market features

Source: authors' elaboration

3.1. Econometric Approach

As explained in the theoretical framework (section 2), our idea is to represent the impacts of the evolution of labour demand on income inequality by using a two-step approach, first considering the factors that, sector by sector, influence the share of high skilled labour demand, and then assessing the impact of this skill bias effect on income inequality.

The analysis presented here aims at representing these hypothesized relationships empirically. Consistent with the theoretical background, the econometric approach is made up of two connected steps: in the first one we estimate a very simplified econometric model of skilled labour demand at sector level, which helps us to set up a rough test of the theoretical hypothesis of Acemoglu (1998), by considering two different factors which probably affect skilled labour demand: R&D expenditure on the one hand, and overall investments on the other. Thus, on the right side of the equation we omit capital stock, and consider R&D and investments, besides wages and value added. Of course, in our case, we can formulate the usual expectations about the influence of R&D on the dependent variable, but cannot do the same about overall investments. Actually, as a proxy of general technology fully embodied in capital goods, investments may incorporate skill-replacing innovations rather than skill-complementary ones. This first model can be represented in its implicit form as:

$$HRST_{ijt} = f\,(R\&D_{ijt}, INV_{ijt}, VA_{ijt}, REM_{ijt}) \qquad (1)$$

where HRST is the high-skill share of labour demand, R&D are research and development expenditures per employed person, INV are investments per employed person and REM are remunerations. Subscripts i, j and t identify the 14 countries, 8 sectors and 7 years, respectively.

The second step is the estimation of the effects of this (sector) skill bias on income distribution at country level. So we include the estimated values of the first equation for the eight sectors among the (other traditional) regressors of the second equation, in which the endogenous variable is overall income inequality. So the single variable derived from the first model becomes eight different sector variables (e.g. HRST share in primary sector, HRST share in low-tech sector, etc.):

$$INEQ_{it} = f\,(\widehat{HRST}j_{it}, ECON_{it}, LAB\_MKT_{it}, DEM_{it}, INST_{it}) \qquad (2)$$

where INEQ is the inequality measure (Gini coefficient), $\hat{HRST}_j$ are the eight (j = 1, 2, …,8) fitted variable shares of sector labour demand, and ECON, LAB_MKT, DEM and INST are baskets of economic, labour market, demographic and institutional variables, respectively. (The explicative variables are listed in the description of the data in section 3.1.) Subscripts i and t refer, as above, to countries and years.

The use of the fitted values of the first regression aims at representing econometrically the theoretical scheme of figure 1, i.e., technological change affects income distribution *via* labour demand – and thus productivity and wage – evolutions.

The estimates were made using the panel data econometric technique, corrected for heteroskedasticity and autocorrelation. As explained, the first model pooled countries, sectors and years, the second one only countries and years (as the inequality measure obviously refers to the country level). Since we could assemble a dataset of 14 countries and 7 years (with few missing values), the second equation was estimated on a basis of 98 observations. Consequently, the number of explanatory variables had to be kept to a minimum by excluding non-significant variables (also as regards country and time-specific effects) and keeping only the most steadily significant ones in the estimated model.

3.2. Results

Some preliminary statistics for the panel data estimation of equation 1 can be examined in table 3. As mentioned above in section 3.1, the SBTC hypothesis was tested for 14 countries times 8 sectors over 7 years (1995-2001). Therefore the expected total number of groups (or panels) is 112 and the total number of observations 784. Unfortunately, we could not obtain complete information for all variables: due to lack of data in the dependent variable (HRST) and R&D expenditure we only obtained an unbalanced panel.

In any case, the strong difference in variability between and within the groups is worth noting. For all variables, the temporal variability within each sector of a given country is very small when compared with the between-groups one.

This first result led us to make a within-group estimation by taking into account both the possibility of heteroskedasticity between groups and serial autocorrelation within groups. The presence of autocorrelation in this panel data model was detected using the Wooldridge (2002) test.

Table 3

Preliminary statistics for panel data estimation of SBTC hypothesis (first step)

Variable		Mean	Std. Dev.	Min	Max	Observations	
HRST	overall	0.19	0.14	0.00	0.80	N	720
	between		0.14	0.01	0.72	n	111
	within		0.02	0.03	0.27	T-bar	6.49
VA	overall	33.50	22.26	2.84	111.97	N	784
	between		22.11	3.21	107.73	n	112
	within		3.18	9.81	57.90	T	7
R&D	overall	0.72	1.65	0.00	12.49	N	728
	between		1.64	0.00	9.47	n	105
	within		0.25	-1.58	3.75	T-bar	6.93
REM	overall	17.51	11.23	1.41	49.96	N	784
	between		11.17	1.55	42.90	n	112
	within		1.56	6.70	27.06	T	7
INV	overall	7.66	7.17	0.58	36.47	N	784
	between		7.07	0.92	31.90	n	112
	within		1.35	1.09	17.59	T	7

N = total number of observations
n =number of groups
T = number of years

HRST = share of human resources in science and technology to total employment
VA = added value per employed person (.000 Euro)
R&D = research and development expenditure per employed person (.000 Euro)
REM = average wage in sector (.000 Euro)
INV = investments per employed person (.000 Euro)

Source: authors' elaboration

The Feasible Generalized Least Square (FGLS) estimator is very often considered an optimal solution to correct for heteroskedasticity and serial correlations in within-group estimations (Arellano, 2003), and we used it to test the SBTC hypothesis in this first step of our analysis. The results of table 4 show that all variables introduced to explain the skilled labour demand of the European countries in the period 1995-2001 are significant, with the expected sign, although the magnitude of the coefficients is not particularly high. The introduction of country and sectoral dummies improves the explanatory capacity of the model, probably because they capture specific structural and institutional factors that operate at two different levels (e.g., a specific country's labour market regulations, and the specific structural and regulative context featured by the EU at sectoral level).

First of all, it is interesting to note that R&D expenditure is the variable that most significantly influences skilled labour demand. An increase of 1,000 Euro per employed person in R&D investments caused a growth of 1.58% in the proportion of skilled labour. This outcome highlights the fact that skill-complementary technologies have a crucial role in that period.

Table 4

Results of first-step estimation: SBTC hypothesis

Coefficients: generalized least squares Panels: heteroskedastic Correlation: common AR(1) coefficient for all panels (0.836)	Number of obs. = 666 Number of groups = 103 Obs. per group: min = 5	
Wald chi2(17) =3588.47 Prob > chi2 = 0.0000		
Dependent Variable: HRST	Coefficients	P-values
VA	0.001	0.000
R&D	0.016	0.000
REM	0.002	0.000
INV	-0.001	0.016
Country dummies	Yes	Yes
Sectoral dummies	Yes	Yes
Constant	0.001	0.941

Source: authors' elaboration

Overall investments per employed person inhibits the demand of qualified workers, although the small value of the coefficient offsets this negative and significant influence.

These opposite effects and their sizes probably explain the increasing trend of skilled labour shown in diagrams 1, 2 and 3, and confirm Acemoglu's hypothesis concerning the existence of skill-replacing technologies embodied in new capital, introduced through investment flows.

As regards the remaining control variables, the positive role played in particular by the wage levels must be noted. Of course, in this case, we are dealing with overall wage levels and do not distinguish *HRST/no-HRST* wages. Therefore, it is reasonable to suppose that an increase in workers' remuneration incorporates incentives and skill premia for more qualified personnel. At the same time, this result provides us with indirect proof of the wage inequality effect: in sectors with higher wage levels we also find higher shares of personnel occupied in science and technology fields.

These empirical findings further encouraged us to use the fitted values of HRST as a determinant of income inequality. Indeed, the proportion of skilled labour resulting from the first estimation is not only adjusted by skill-biased technological change, but is also characterized by a sectoral breakdown which could turn out to be useful in the second-step estimation.

Before we illustrate the results of the estimation of the second equation, diagram 6 presents a group of scatter plots showing inequality levels and $\widehat{HRST}_j$. The main information emerging is the prevailing negative relationship between inequality and the share of skilled labour in most sectors. This visual information is confirmed by the size and significance of the correlation coefficients: -0.70 for primary and non-market services sectors, -0.69 for low-tech and –0.72 for wholesale sectors. The industries with relatively less clear relationships are the high-tech and medium-tech sectors. For the first, a sort of U-shaped relationship emerges. The fitted variables show remarkable levels of correlation among sectors: in particular, on one hand medium and high-tech industries show very similar patterns (correlation 0.75); on the other, the $\widehat{HRST}$ levels for all the remaining sectors are strongly correlated (significant coefficient above 0.8). These aspects were taken into account in estimating equation 2 and in interpreting the outcomes.

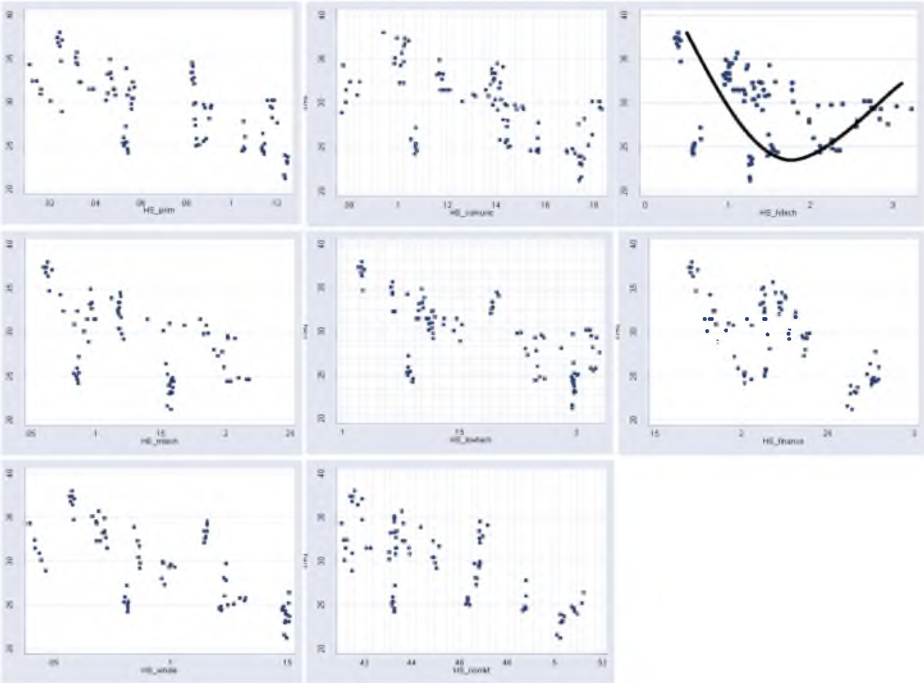

Diagram 6. Inequality measures vs high-skill share of total labour demand (fitted $\widehat{HRST}$ values)

Source: authors' elaboration

Table 5 illustrates the outcomes of the estimation of equation 2. As already explained, we excluded non-significant variables and kept only those steadily significant in the estimated model. Very few variables survive in the final model, partly due to the high levels of correlation among the regressors, as previously illustrated. As regards socio-economic variables, the model clearly shows a Kuznets effect, represented by the significance and signs of the per capita GDP variable, and its square. Similarly, increasing female employment rates are associated with a reduction in inequality. This is consistent with the hypothesis that the entrance of women into the labour market, favouring integration of household incomes, acts as a factor reducing inequality (Bradbury, 1990, in Partridge *et al.*, 1996). Conversely, growing employment rates of people aged 55-64 are associated with increasing inequality. This outcome may look counterintuitive, although it may be explained in terms of informal human capital endowment, and so productivity and wages, which can be imagined higher as the age of workers increases (Partridge *et al.*, 1996).

Table 5

Determinants of income inequality

Coefficients: generalized least squares Panels: heteroskedastic Correlation: common AR(1) coefficient for all panels (0.3509)	Number of obs. = 90 Number of groups = 14 Obs. per group: min = 4	
Wald chi2(17) = 1362.33 Prob > chi2 = 0.0000		
Dependent Variable: Gini	Coefficients	P-values
FER	-0.196	*0.000*
Old ER	0.235	*0.000*
Per Capita GDP	0.315	*0.000*
Per Capita GDP^2	-0.001	*0.003*
$\hat{H}\hat{R}\hat{S}\hat{T}$ low-tech	-0.505	*0.000*
$\hat{H}\hat{R}\hat{S}\hat{T}$ high tech	-0.863	*0.000*
$\hat{H}\hat{R}\hat{S}\hat{T}$ high tech^2	0.017	*0.000*
D 1995	0.518	*0.081*
D 1997	-0.463	*0.042*
D 1998	-0.653	*0.004*
D Belgium	5.078	*0.000*
D France	6.395	*0.000*
D Greece	2.352	*0.032*
D Netherlands	3.512	*0.000*
D Poland	11.533	*0.000*
D Slovenia	5.523	*0.000*
Constant	28.687	*0.000*

Source: authors' elaboration

As regards the focus of this paper, a growing share of high-skill labour in the low-tech sector (and in the other correlated sectors) reduces inequality, while a quadratic relationship emerges for the high-tech sector (which was strongly correlated with the medium-tech sector). For the purpose of interpretation of these outcomes, we recall here that the SBTC effects envisaged by Acemoglu (1998) (see section 2.1) may be differentiated among sectors, so that the composition of the industry-specific effects on overall income inequality may be complex and depend on the share of high-skill labour in a given sector, the weight of that sector on the total economy, and the sector-by-sector wage differentials, levels of skills being equal. These complex interactions may help to explain the outcomes obtained. If, as is likely, wage levels in the high-tech sector are relatively high compared with other sectors, skill intensity being equal, the adverse effects of high-skill labour on overall income inequality may emerge when the share of workers with high skills increases and when the importance of the sector grows. This may explain the positive trend of the relationship taking place beyond a certain threshold of the importance of the sector and of high-skilled labour. Similar considerations may be made as regards medium-tech sectors. It should be noted how, taken together, the medium- and high-tech sectors on average account for around 15% of total employment in the sample considered. The negative sign for the low-tech sector (highly correlated with all the remaining primary and services industries) clearly indicates that growing high-skill labour shares reduce inequality. Apart from wage differential effects within the single sectors (for which SBTC may exist), different explanations for this negative impact on overall inequality may lie in the specificity of the single sectors or, again, in wage differences between sectors (skill levels being equal). For example, in one important sector such as non-market services (in terms of weight on country employment, accounts on average for around 30%), the high-skill labour share is remarkable but the wages of this segment are probably relatively lower than in the case of comparable skilled labour in other sectors, as the wage levels are not directly linked to productivity (for example, in the case of public administration). So the growth of skilled labour, in this case, only contributes towards reducing overall inequality, allowing the wages of workers in these sectors to converge towards average levels. The same interpretation may apply to the low-tech, primary, communications and wholesale sectors: it is probable that a graduate in these sectors will be working on tasks (e.g., accounting) different from those of a graduate in medium- and high-tech industries (engineering, R&D, managerial tasks), with a consequent relatively lower level of earnings. These conjectural interpretations should of course be supported by empirical evidence on wage differences among sectors (for the same skill endowment), so further research is needed on the topic from this point of view.

However, beyond these hypothetical explanations, we must also consider factors related to labour supply and the fact that for some sectors (e.g., non-market and traditional services sectors), the initial slowdown of the skill premium envisaged by Acemoglu may be persistent, since no technological leap occurs while a plentiful supply of high-skill labour continues. So, for these important sectors (on total employment), the skill premium and wages for high-skill labour persist at a relatively low level, favouring less unequal distributive structures.

4. SUMMARY AND FINAL REMARKS

Before summing up the main findings of our empirical analysis, it is useful to recall one consideration just touched upon at the beginning of this paper. Indeed, if we adopt a sort of bird's eye view, we may wonder whether, unlike in the past, when skill-replacing technologies dominated the economy and depressed the general demand for skilled labour, an unprecedented relationship among new skill-complementary technologies, qualified labour demand and income distribution has been characterizing the most recent era.

Clearly, the answer to this question goes beyond the scope of our rather simple empirical analysis and the arguments discussed in it. Nonetheless, we think that the core of the same answer relies on the identification of the opposite forces that currently operate in the labour market and the varieties of contexts by means of which these forces, among others, influence income distribution and inequality.

In this paper we tried to move forward in the above-mentioned direction. More precisely, the aim of our empirical survey was to explore the role played by skilled labour demand considered at sectoral level, as a determinant of inequality, in fourteen European countries in the period 1995-2001. This analysis was articulated into two steps, one estimating the effect of skill-biased technological change in the labour market, and the other using this sort of instrumental variable that is, skilled labour demand incorporating the effect of technologies, wages and output – as a determinant, together with others, of inequality.

In the first step, we identified two opposite driving forces of skilled labour demand: R&D expenditure, which clearly pushes upward the share of qualified workers to total employment, and overall investments which depress that demand, probably because in the total new capital included in general investments skill-replacing technologies are dominant. The fact that this negative effect is much smaller in magnitude than the positive R&D effect probably explains the unquestionable increase of the proportion of skilled labour in the last few years. Of course, in future development of this research, skill-replacing technologies should be identified more precisely, since the generic variable used here (investments) is only partially able to do this.

The remuneration per employed person plays a positive role in the demand for human resources in science and technology, although the magnitude of its effect is very small. This result indirectly tells us about the minor role played by wages and anticipates an important result emerging from the second step: most sectors show that the higher the proportion of qualified workers, the lower the inequality in that country. Therefore, there is a component of the qualified labour force, probably not determined by skill-biased technological change, that seems to be poorly correlated to wage inequality.

The second step estimations highlighted the generalized negative and significant impact on inequality of an increase of skilled labour demand in low-tech sectors. Conversely, in hi-tech sectors, which are highly correlated to medium-tech ones, a quadratic relationship emerges in which under a given threshold the higher the demand for qualified workers, the lower the inequality, but beyond that threshold, inequality increases. If we consider that all services and the primary sector are highly correlated with the low-tech sector, a combination of factors such as (i) the industry weight on total economy, (ii) the skill premia paid within the same industries, and (iii) wage differences between sectors (skill levels being equal), may help to explain this phenomenon. In particular, it is probable that the wages of high-skill workers in the low-tech sectors and traditional and non-market services are lower than those of equally high-skill workers in medium- and high-tech sectors. If this is true, when the share of skilled workers increases in the low-tech and services sectors, a higher number of relatively worse paid employees enhances their living standards. However, this is not enough to increase overall inequality, but may allow the convergence of their incomes towards average values. This mechanism may be reinforced if the skill premia within these sectors are not particularly remarkable.

Moreover, according to Acemoglu's hypothesis, it is probably the lack of an adequate market size of skill-complementary technologies in the low-tech and non-market service sectors (such as public administration, education, etc.) that causes an abundance of skilled labour supply which decreases skill premia and wage inequality.

These hypothetical interpretations need further research efforts aimed at considering the wage differences produced by different skill endowments within single sectors and between sectors. However, this is a difficult task, considering the shortage of data on wage differences according to human capital endowment. A further point that may help to explain the main result of this paper (negative effects on inequality of the growing high-skill share of workers in low-tech and traditional and non-market services) may be found in the fact that the initial effect of the Acemoglu mechanism (slowing-down of skill premia induced by expanded labour supply) may be persistent, since no subsequent technological leap occurs (this is especially true for the non-market and traditional services sectors) and no significant productivity gains emerge. So the high-skill labour supply may be persistently high, as is the case in many European countries for certain segments of the labour market, and this may contribute towards controlling wage disparities and thus, inequality.

Conversely, beyond a given threshold, qualified workers in hi-tech sectors form a consistently privileged and rich working class which contributes towards widening the gaps in living standards.

Although further research in the direction mentioned is needed, this paper provides some new insights about the role of labour market features in shaping income inequality and poses, on policy grounds, the crucial question of the complex management of interventions aimed at fostering R&D activities and human capital developments, given the different sectoral consequences in terms of the labour market and inequality outcomes.

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Received: June 2007