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Abstract

This paper provides empirical evidence of the link between technological change in different technology intensive sectors and overall income (and not simply earnings) inequality in some EU eastern and western countries. In a first step, skill-biased technological change hypothesis is tested distinguishing various technology intensive sectors: results confirm the presence of skill-complementary technologies but also stress the skill-replacing character of other ones incorporated into investment flows. The second step places the evolutions of sector skilled-labour demand among other traditional determinants of income inequality. Findings reveal significant and composite impacts of skilled-labour demand, strongly depending on sectoral differences in technological intensity.

J.E.L. Classification: O33, J24, D31, O15

Keywords: technological change, skills, income distribution

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1. Introduction

There is increasing interest in the study of the impact that skilled labour demand and returns to skills have had on distributive patterns in recent years. Since the 1990s, theoretical studies or empirical analyses, often focused on the United States, have especially highlighted the importance of technological determinants in the evolution of earnings inequality (Levy and Temin, 2007; Glaeser, 2005; Pianta, 2003; Pianta, 2001; Slottie and Raj, 1998; Levy and Murnane, 1992; Katz and Murphy, 1992). As shown in detail below, Acemoglu (1998, 2005), among many others, has clearly explained why a non-neutral technological change entails distributional implications. Indeed, if it benefits some segments of factors of production (first of all labour) while reducing the compensation of others, it is important to ascertain which groups will be the winners and which the losers as a result of technological progress and, in turn, how this process affects overall economic inequality among and within countries.

Starting from these considerations, this paper aims at shedding light on the complex relationships between technological change, quantitative and qualitative labour demand dynamics, and income (not simply earnings) distribution.

Our theoretical (and, consistently, empirical) approach, which is essentially explorative, is composed of two connected steps.

In the first one, the effects produced by technological change on the share of high-skill labour demand are analysed. A first distinctive characteristic of the paper is the provision of a sectoral breakdown of the analysis of skill-biased technological change (SBTC), in order to highlight in which particular manufacturing or service sectors, classified by technological intensity, skilled labour demand evolved more markedly.

In the second step, we attempt to provide empirical evidence of the impact of these sector demand dynamics on overall income inequality, rather than on the usually considered earnings inequality. This is the major innovation of the paper, which is indeed aimed at answering the following question: if SBTC effects exist and are diversified among sectors, how much and in which direction are they able to affect overall income distribution? As clearly underlined by Atkinson and Brandolini (2006), the distribution of individual earnings is related to, but different from, household income distribution, due to the roles of other income sources (capital, self-employment, rent, transfers, etc.) and of the family itself. Moreover, other systemic factors (of demographic, institutional, economic nature) also affect income distributive patterns. So, rising (decreasing) earnings inequality is just one possible, although important, factor affecting rising (decreasing) income inequality, and must be placed inside a more complex set of determinants.

Another distinctive feature of the paper is the inclusion, in the sample of EU countries considered, of some important new Eastern members. So far, the question of income inequality in transition economies has been analysed from many points of view: for example, among others, by studying the relationship between inequality and growth (Sukiassyan, 2007); stressing the polarization of state transfers (Kattuman and Redmond, 2001), or exploring the role played by informal economy (Rosser *et al*., 2000). However, the shift in composition of labour demand towards skilled labour and its consequences for income distribution has been much less frequently studied.

The paper is structured as follows. We first present our framework of reference, 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, we first describe the dataset employed to test empirically, in a set of Eastern and Western EU countries, the validity of our scheme of interpretation. After providing information on the variables used and some basic descriptive analysis (§ 3), we describe the econometric approach adopted and the results obtained (§ 4). Section 5 summarises the results and concludes.

2. The Theoretical Framework of the Empirical Analysis

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. In section 2.1 we briefly consider, without any claim of exhaustiveness, the effects produced by technological change on various skill segments of labour demand. In section 2.2, we place these effects among the determinants of income inequality, as traditionally identified in the literature.

2.1 Skill-Complementary Technologies and the Labour Market

It is widely known that, since the microelectronics revolution in 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 industrialised countries (Wood, 1995; Mishel and Bernstein, 1998; Berman *et al.*, 1994; Machin and Van Reenen, 1998, Aghion and Howitt, 2002¸ Piva *et al.*, 2005).

This is in contrast with the dominant skill-replacing innovations of the nineteenth and twentieth centuries, when the transition from artisan-based to factory-based systems of production (Marx, 1961) and the subsequent massive introduction of Tayloristic methods (Braverman, 1974; Goldin and Katz, 1998) were at work. The novelty of the current era seems to be the skill-complementary character of many technologies (Redding, 1996; Acemoglu, 1998; Piva *et al.*, 2005).

An interesting theoretical discussion concerning this skill-biased technological change hypothesis is provided, among many others, by Acemoglu (1998), who shows 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., difference between earnings by college graduate as opposed to 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 (and so wage dispersion) rise above their original levels (Acemoglu, 1998, p.1057).

Of course, SBTC mechanisms regard 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 earnings inequality (and subsequently on income inequality) are the result of the complex composition of single sectors situations.

In this paper we certainly rely on the above-mentioned theoretical considerations to test the SBTC hypothesis in European countries for recent years, but we also move from previous findings provided by the empirical literature.

First of all, there is important international evidence of the significantly pervasive role played by SBTC in the shift of skilled labour demand in developed countries (e.g., Berman *et al.*, 1994). According to these authors, the substitution towards skilled labour within industries occurring in ten OECD countries - in particular, the same manufacturing industries that substituted towards skilled labour in the United States in the 1980s - also occurred in the other developed countries. The pervasiveness of SBTC is the main explanation of the phenomenon, although the same effects may be reinforced by growing trade integration (Barro, 2000; Li *et al.*, 1998; Richardson, 1995) which normally accelerates the rates at which new technologies are adopted and skilled labour demanded (Kim, 1997; Wood, 1995), according to countries' specialisation patterns. As suggested by the standard theories of international trade in the presence of sector-specific factors, in better-off countries relatively richer in human and physical capital, growing trade openness drives low-skilled wages downwards *via* increased flows of unskilled-intensive imports. At the same time, growth of skill-intensive exports should raise the relative demand of high-skilled workers, widening the relative wage gap and thus fostering inequality. Similar results are to be expected if the international integration process also regards labour and capital. The opposite specialisation pattern and distributive dynamics should be observed in developing countries (Robbins, 1996). This interpretation has, however, been largely criticised (see, e.g., Ghose, 2000; Machin and Van Reenen, 1998) and conflicts with various pieces of empirical evidence and widespread opinions about the distributive consequences of globalisation processes (see, for example, Barro, 2000; Dollar and Kraay, 2004). For a recent theoretical and empirical discussion about the complexity of the effects of globalisation on employment, income distribution and poverty in developing countries, see Lee and Vivarelli (2006).

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 (e.g., 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. The key explicative 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, although 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 of their study lies in the observable indicators of technology, which extend the traditional econometric model of 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.

Various interesting contributions (e.g., Card and Di Nardo, 2002; Lemieux, 2006) has challenged this widespread SBTC hypothesis, casting doubts on the persistence of shifts of skilled labour demand since, after an initial period (early 80s for the US) of growth, wage dispersion stabilised. However, in the dynamic framework proposed by Atkinson (2007), if the relative supply of skilled labour catches up with demand increases, persistent shifts of skilled labour demand are consistent with constant wage differentials. This does not mean that earnings dispersion is also stable, since as the share of skilled workers grows, this reduces the income shares of top and bottom sections of the distribution. Atkinson (2007) also criticised the simplified approach of the SBTC hypothesis moving from the large empirical evidence of the last decades, when wage dispersion increased as a result of the rise of top decile (relative to median), which was not necessarily accompanied by a fall of the bottom decile. Moreover, within the upper part of the distribution, the top decile has been growing more than the top quartile, so that a "fanning out" dynamic took place. This is explained in terms of shift of norms determining the link between individual earnings and productivity, and combining "superstar" theory with the approaches explaining pay structures in hierarchical organisations.

2.2 The Determinants of Income Inequality

Economists mainly focus on the long-term and persisting attributes which give rise to different patterns of income distribution among countries and which reduce dynamics within them (Li *et al.*, 1998).

Consistently with the aims of this paper, we first consider, among other key structural determinants of income inequality identified in the literature, the role attached to human capital endowments.

A first important channel connected with human capital has already been described in section 2.1. The SBTC hypothesis support the idea that higher skill premia, stemming from more 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 income inequality determinants these aspects are often considered from the perspective of labour supply. For example, Panizza (2002) and Barro (2000) associate low levels of average human capital endowments of the population with a reduced capacity to gain access to job positions (or to use technological developments) which would guarantee better income opportunities. Other authors directly focus on 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 (e.g., Partridge *et al.*, 1996). Again from 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 the reduced capacity to limit the lobbying capacities of the "rich minority" which tends to impose anti-distributive policies (Li *et al.*, 1998)[1].

[1] Again, from a political economy viewpoint, the degree of democratisation (existence of civil liberties) of a country is a crucial factor, since it imposes important constraints on the richest share of the population, weakening its conservative

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), with inequality growing at initial stages of development and decreasing in further stages. This pattern is basically explained in terms of effects produced on relative wage dynamics by labour mobility during the transition from a rural/agricultural to an urban/industrial or tertiary economy. This "internal" migration explanation is joined, in analysis of inequality in developed countries, by arguments related to various and complex effects produced by structural change. The focus is not only on the effects of industry structure changes, i.e., the decline in farming and manufacturing in favour of tertiary activities, but also on the qualitative evolution of labour demand within sectors and its interactions with some features of labour supply, i.e., human capital (as pointed out above).

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 explicative factors is associated with labour market efficiency (employment / unemployment rates) and with the consequences of specific demographic features, 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 unionisation and centralised bargaining should create more homogeneous wage level distributions (Partridge *et al.*, 1996), although much depends on the industry mix of the economic system considered.

Again, from an institutional point of view, the role of social security systems is also often emphasised by assessing the impact of differing social security arrangements on distributive patterns (e.g., Esping-Andersen, 1990; Korpi and Palme, 1998; Castles and Mitchell, 1992), although the inverse causal direction of the relationship is debated[2]. A more generous social security 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) consider, beyond the size of the social security systems, the impact of some of their features (e.g., centralisation, coverage and duration of benefits).

3. Empirical Analysis: Data Sources and Variables

The objective of the empirical analysis is to represent the possible effects of technological change on income distribution *via* the evolutions of the share of skilled labour demand. Before entering the econometric approach and results (section 4), we provide here a description and discussion of data and variables used, again distinguishing the two phases: (i) skilled labour demand dynamics and (ii) income inequality patterns.

3.1. Skills, Technology and Labour Demand Evolutions

As discussed in the previous sections, the first step of an analysis testing the SBTC hypothesis needs a reliable indicator of skilled labour on the left side of the skilled labour demand equation. Identification of white-collar workers with skilled workers and blue-collar workers with unskilled ones is quite common in the literature, but not completely exhaustive. Actually, the white-collar category very often includes subsets

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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.

[2] 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.

of unqualified workers, such as certain type of clerical personnel, whereas highly qualified manual workers are classified as unskilled labour because they are not provided with a formal level of higher education. For these reasons, we use here recent statistics released by Eurostat concerning Human Resources in Science and Technology (HRST) (Eurostat, 2007a). 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 kinds of occupations typically require successfully completed education at the third level, corresponding to 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 experienced 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 focus on business expenditure in R&D, investments, remuneration of labour and value added.

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 this indicator seems more suitable for proxy complementary-skill technologies in the field of SBTC studies.

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

Unfortunately, capital stock data for CEEC countries and for recent years are not available. For the main international and official statistical sources (such as Cambridge Econometrics, Eurostat, OECD, UN, Penn Word Tables) not only data on sectoral breakdowns but also whole capital stock at country level for CEEC are missing[3]. For this reason we used investments instead of capital stock, by assigning to our skilled labour demand specification a meaning slightly different from the traditional one (Piva *et al*. 2005) but consistent with our theoretical framework.

In our case, the investments variable is a proxy for overall new technologies embodied in new capital. According to Acemoglu (1998), technologies are complementary-skill 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 complementary-skill 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 perform this role.

As regards the remuneration of labour and value added, 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 normalised by the number of employees at sectoral and country level. Consequently, we regress the *share of HRST to total employment* (skilled labour demand) to *per capita R&D expenditure* (R&D), *per capita investments* (INV), *per capita value added* (VA), and *average remunerations* (REM) 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 lack of data: these are ten Western members (Belgium, France, Germany, Greece, Ireland, Italy, The Netherlands, Portugal, Spain and UK) and four new members (Czech Republic, Hungary, Poland and Slovenia).

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[3] Information on the different kinds of assets and depreciation rates for CEEC countries, useful for estimating capital stock starting from investments and applying the perpetual inventory method, was not available.

We also aggregated some sectors cording to differing technology intensity, 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 statistical reasons. For example, the distinction of manufacturing into *high-tech*, *medium-tech* and *low-tech* is functional to verifying whether SBTC is an exclusive phenomenon concerning emergent and dynamic industries, or whether it an 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

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 *UE-25 average*, are examined. The different length of the lines is due to lack of data.

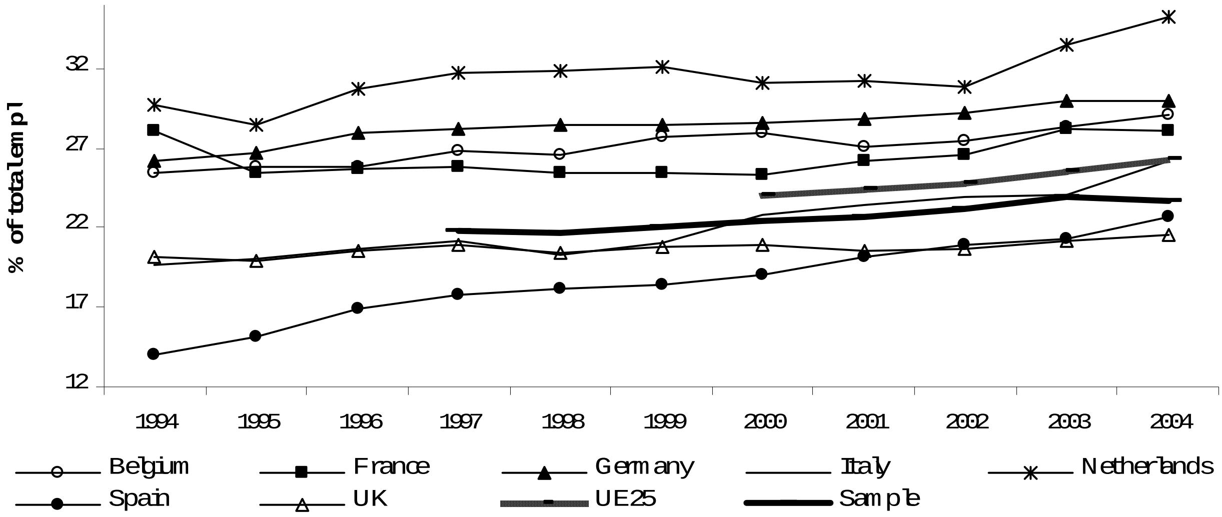
As regards the older UE members, diagram 1 displays an overall increase in the share of HRST over total occupation, although Spain and the UK remain below both sample and UE-25 averages. For Italy, a sort of catching-up process seems to be working, because this country exceeded the sample average in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

The comparative situations of the UK and Italy are 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 was below the UE-15 average, the value of this indicator increased for the UK but decreased for Italy (Eurostat, 2007b)[4].

In the remaining four countries of diagram 1 (Belgium, France, Germany and The Netherlands), the evolution of skilled labour demand showed levels above the UE-25 average (26%). The position of these countries seems, at first sight, to be more consistent with the view of this 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 (2007b).

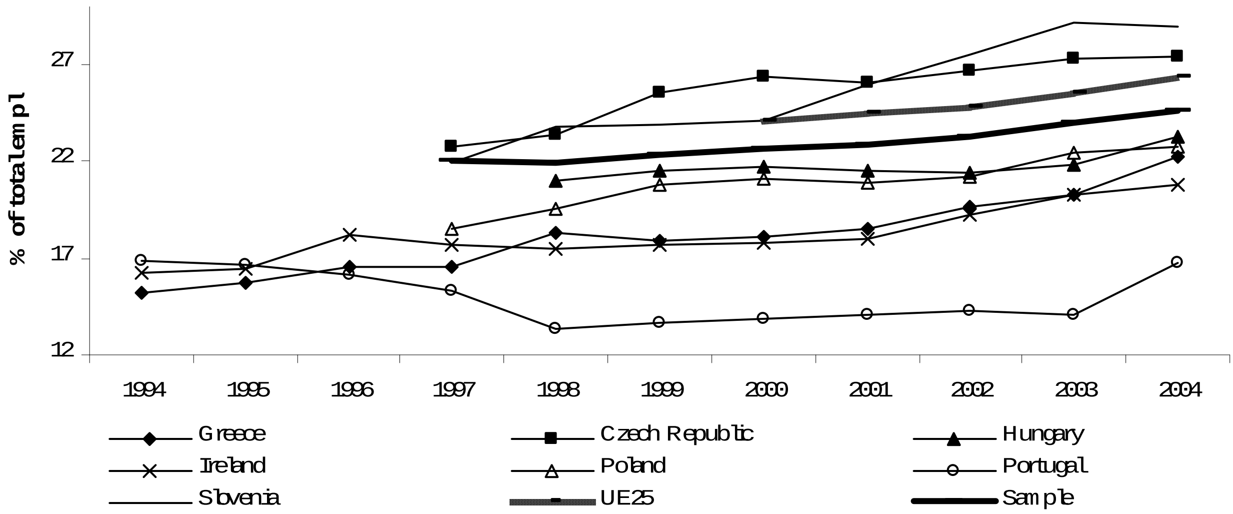
[4]This result needs to be further analysed in the future, although a preliminary explanation may be found in the different sectoral trends of human capital between UK and Italy, and in the different sectoral *HRST* composition resulting in 2004. For the sake of brevity, the descriptive analysis does not show the sectoral breakdown of this variable at country level, although it is taken into account in the econometric analysis. However, it is sufficient to consider here that *HRST* in hi-tech sectors increased more quickly in the UK (moreover, in 2004, the share of this skilled labour to total employment was 24% in UK and 21% in Italy), whereas the opposite occurred in sectors such as wholesale and non-market services. In particular, in the wholesale sector, in which the marginal contribute of *HRST* is probably not relevant for overall labour productivity at country level, the share of skilled labour to total employment in 2004 was 12.3% in Italy and 2.2% in UK. All diagrams reporting sectoral trends of *HRST* at country level are available upon request.

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



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

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



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

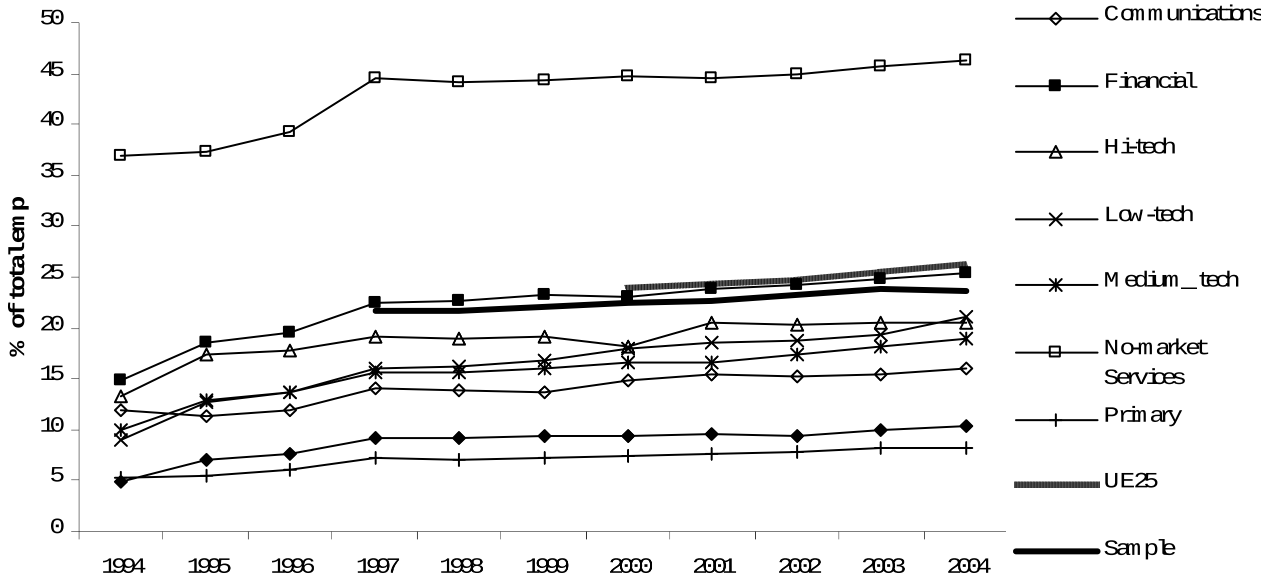
When we analyse skilled labour demand by sectors, we observe a similar overall increasing trend (diagram 3). It is not surprising that the major proportion of HRST is located in non-market services, in which public administration, education activities embodying universities and other public institutions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

In the other sectors, it is worth noting that financial services sector is the only one that shows levels of skilled labour above the sample average. Indeed, within this macrosector, we find advanced business services and specialised market R&S 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. It is probably the consequence of the increasing importance of highly qualified, experienced workers with tacit knowledge gained in the mature industries of countries like Italy and Germany (Eurostat, 2007b).

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

Diagram 3. Skilled labour demand by macro-sectors



3.2. Measures of Income Inequality and of its Determinants

As explained before, the second step of our analysis consists of including sector labour demand dynamics among the determinants of overall inequality. As for information about inequality levels, the data are 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)[5]. This database collects and processes inequality measures calculated by various national and international institutions. Considering the availability of data for the explicative variables, we were able to assemble a panel database covering the 14 countries listed in section 3.1 for the years 1995-2001. For the countries of the old EU (before the 2004 Eastern enlargement), inequality data are drawn from the Eurostat on-line database (2007a); data for the four new Central and Eastern 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[6]. All the labour market, demographic and economic indicators are drawn from the Eurostat on-line database. Considering the existing evidence on income inequality determinants (see section 2.2), we were able to assemble the following indicators: 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 variables used are: bargaining centralisation (centr) and union density (union), which are not available yearly. Thus, the data closest to the 1995-2001 period were 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 the 1995-2001 period. Similarly, the differences among the countries tended to fall. This is illustrated by the decreasing trend of the coefficient of

[5] The database and the user guide are available at: http://www.wider.unu.edu/wiid/wiid.htm.

[6] In the case of the Czech Republic, the Gini coefficient was computed using household weights and no equivalence scale.

variation and by the reduction of the differences between 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

If we look at the single countries, in 1995 Portugal, Ireland, Greece, Italy, Poland and the UK showed a Gini coefficient above 30, whereas 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

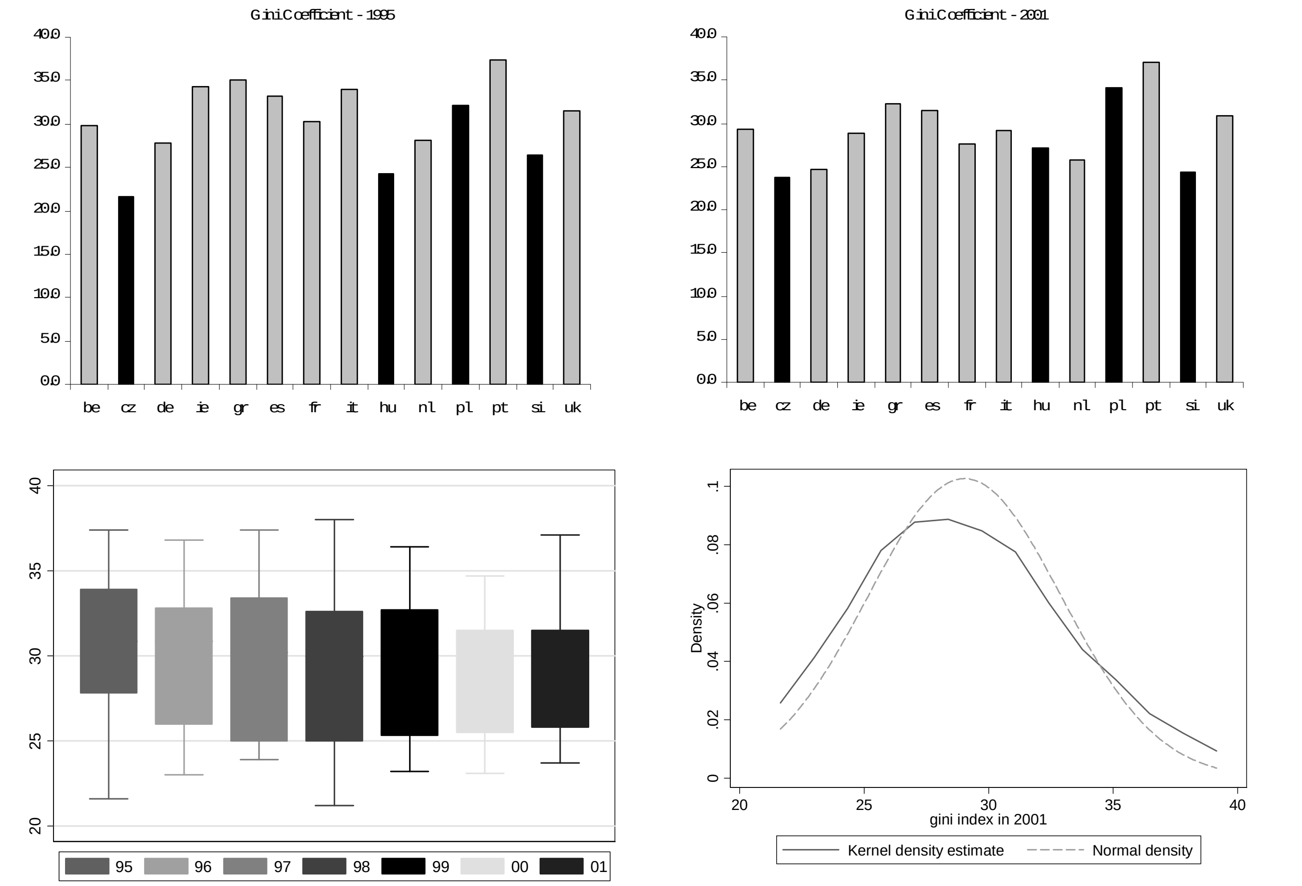
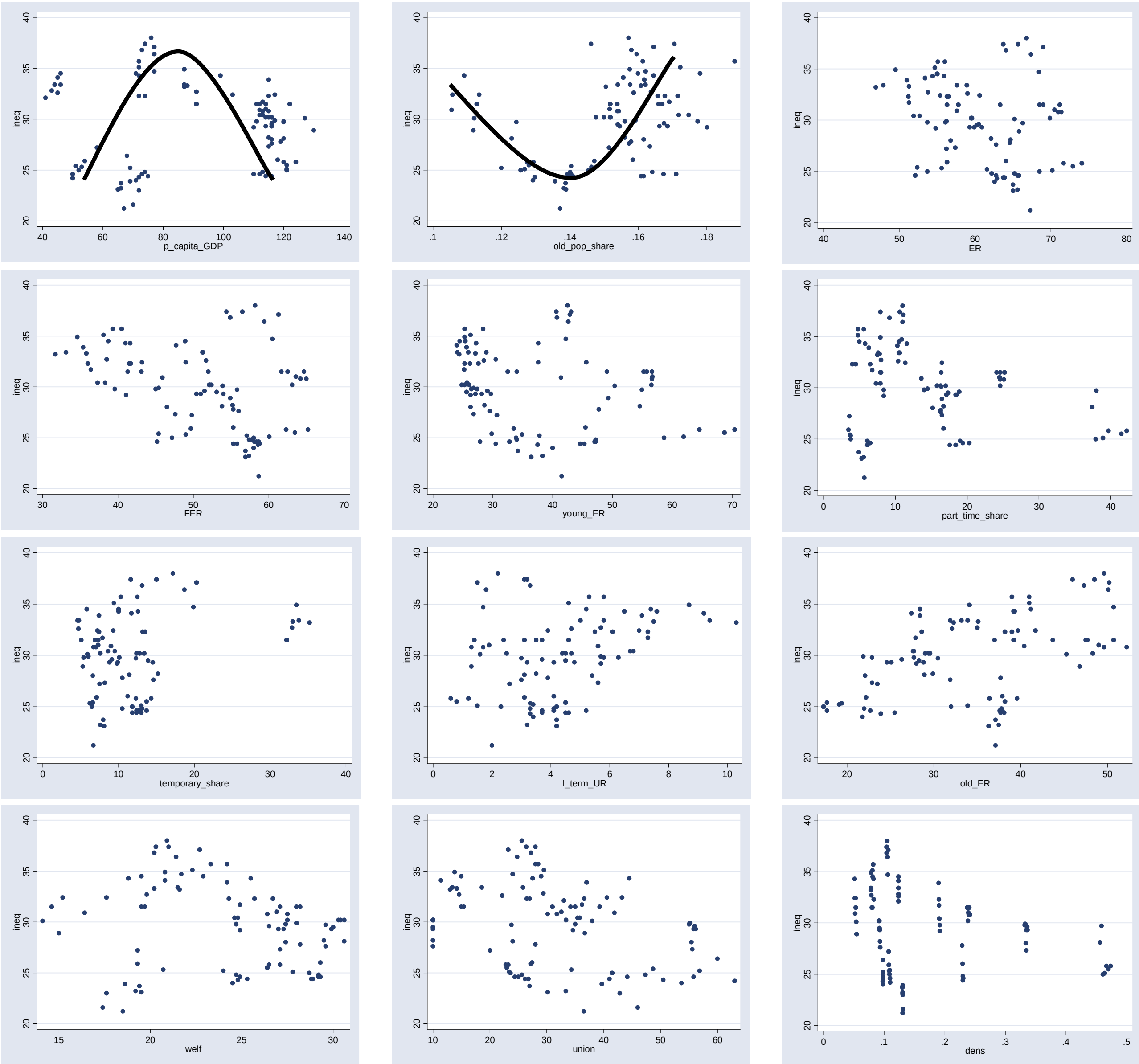


Diagram 5 shows a set of scatter-plots in which the Gini coefficient is plotted against various economic and labour market variables, and reveals some interesting relationships. An example is the case of per capita GDP, in which the inverted U-shape explained by Kuznets is clearly identifiable. An opposed interpolation curve 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 and economic, demographic and labour market features



4. Econometric Approach and Results

As explained in the theoretical framework (section 2), our idea is to represent the impact 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. So, the panel econometric approach is made up of two connected steps: in the first, we estimate a simplified econometric model of skilled labour demand at sector level, which helps us to set up a simple test of the theoretical hypothesis of Acemoglu (1998), by considering two different factors which probably affect skilled labour demand: R&D expenditure and overall investments. 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 average remunerations. Subscripts *i*, *j* and *t* identify the 14 countries, 8 sectors and 7 years, respectively. The time span of the model is limited to 1995-2001 in order to consider the same period available for the second step of analysis. 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.

The second step is the estimation of the impact that these (sector) skill biased effects have on income distribution. Here the dependent variable is overall income inequality, observed for the 14 countries and 7 years used in the previous estimation. Therefore the number of groups is now 14 and the total number of observation 98. So, while the first model considered countries, sectors and years, the second one only countries and years (as the inequality measure obviously refers to the country level), and the sector skilled labour shares become eight explicative variables. This structural difference in the number of groups between the two datasets prevented the possibility to use, in order to carry out a two-stage estimation, the traditional instrumental variables technique. As a second best choice, we decided to use the fitted values of the first regression in the second model, in order to represent econometrically the theoretical scheme discussed before, i.e., technological change affects the evolution of income distribution *via* evolutions of the share of labour demand. So we included the estimated values of the first equation for the eight sectors among the (other traditional) regressors of this second equation::

$$INEQ_{it} = f\,(\overline{HRST}\,(j)_{it},\ ECON_{it},\ LAB\_MKT_{it},\ DEM_{it},\ INST_{it}) \qquad (2)$$

where INEQ is the inequality measure (Gini coefficient), $\overline{HRST}$ (j) are the eight (j = 1, 2, …,8) fitted variables representing the shares of skilled labour demand in the eight sectors considered, and ECON, LAB_MKT, DEM and INST are baskets of economic, labour market, demographic and institutional variables, respectively[7]. Subscripts *i* and *t* refer, as above, to 14 countries and 7 years (1995-2001).

Some preliminary statistics for the panel data estimation of equation 1 can be examined in table 3. The great difference in variability between and within 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.

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 = value added 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)

[7] The explicative variables are listed in the description of the data in section 3.2.

The presence of autocorrelation in this panel data model was detected using the Wooldridge (2002) test, while heteroschedasticity emerged using the modified Wald test. Considering these features of our dataset, we decided to use the Feasible Generalised Least Square (FGLS) estimator to test the SBTC hypothesis in this first step of our analysis, which is generally considered appropriate in these conditions. 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, sectoral and time dummies improves the explanatory power of the model, probably because they capture specific structural and institutional factors that operate at the different levels (e.g., a specific country's labour market regulations, and the specific structural and regulative context featured by UE 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 the growth of 1.4% in the proportion of skilled labour. This outcome highlights the fact that skill-complementary technologies played a crucial role in that period.

Table 4. Results of first-step estimation: SBTC hypothesis

Coefficients: generalised least squares		Number of obs. = 666	
Panels: heteroschedastic		Number of groups = 103	
Correlation: common AR(1) coefficient for all panels (0.814)		Obs. Per group: min = 5	
Wald chi2(17) = 4362.08 Prob > chi2 = 0.0000			
Dependent Variable: HRST		Coefficients	P-values
	VA	0.001	0.004
	R&D	0.014	0.000
	REM	0.001	0.001
	INV	-0.001	0.000
	Country dummies	Yes	Yes
	Sectoral dummies	Yes	Yes
	Time dummies	Yes	Yes
	Constant	0.091	0.000

Overall investments per employed person inhibit the demand of qualified workers, although the small magnitude of the coefficient offsets this negative and significant influence. These negative effects and their magnitudes 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 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 characterised by a sectoral breakdown which may be useful in the second-step estimation to uncover interesting specificities.

Before we illustrate the results of the estimation of the second equation, diagram 6 presents a group of scatter-plots showing inequality levels and $\overline{\text{HRST}}$ (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- and medium-tech sectors. For the former, 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 $\overline{HRST}$ 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 and high-skill share of total labour demand (fitted values ĤŘŜŤ)

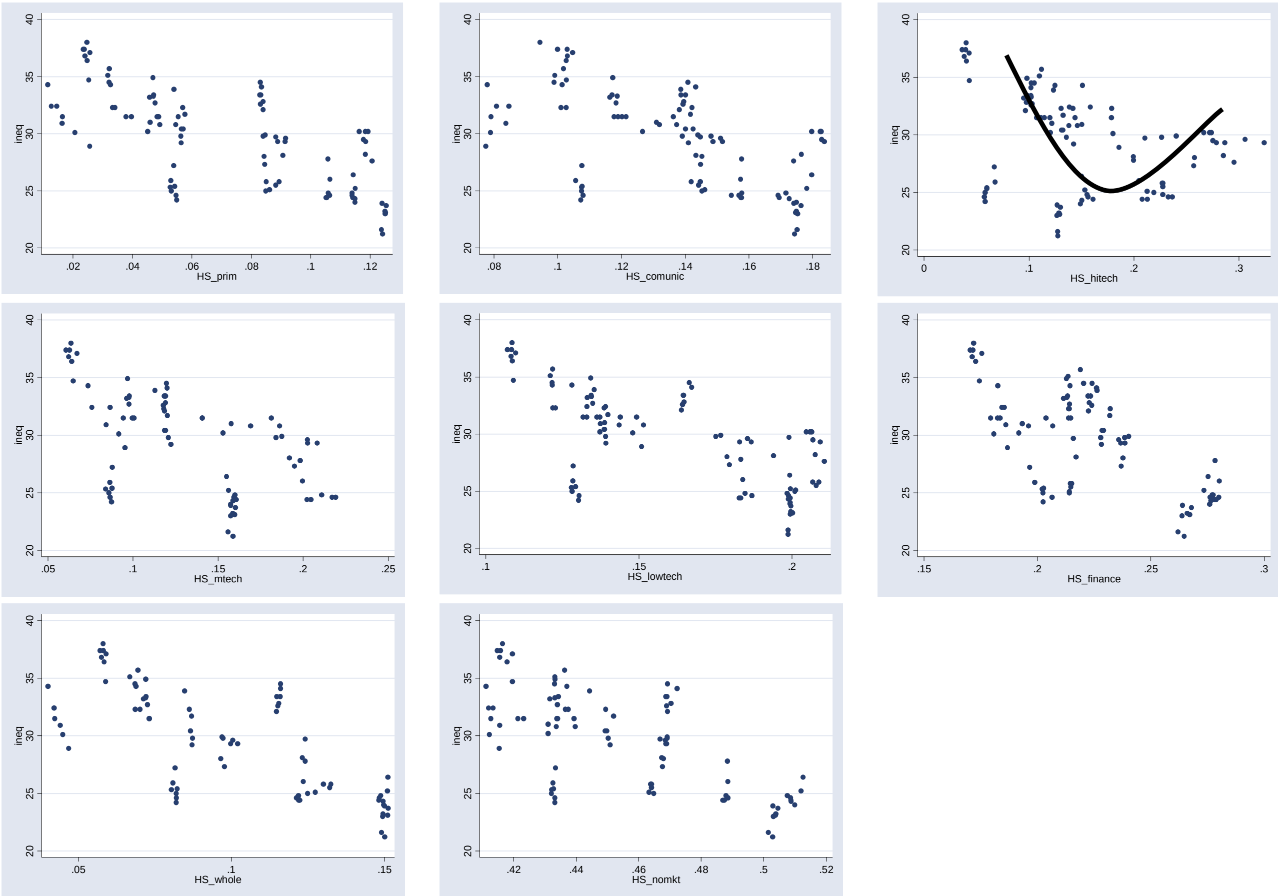


Table 5 illustrates the outcomes of the panel estimation of equation 2, carried out using again Feasible Generalised Least Square (FGLS) estimator, since data presented again problems of heteroschedasticity and serial correlation. Given the limited number of observations (98), the explicative variables 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. Very few variables survived 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 quadratic. 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 may be imagined to be higher as the age of workers increases (Partridge *et al.*, 1996).

Table 5. Results of second-step estimation; determinants of income inequality

Coefficients: generalised least squares	Number of obs. = 90
Panels: heteroschedastic	Number of groups = 14
Correlation: common AR(1) coefficient for all panels (0.2299)	Obs. per group: min = 4

Wald chi2(17) = 1356.33 Prob > chi2 = 0.0000

Dependent Variable: Gini		Coefficients	P-values
	FER	-0.134	*0.000*
	Old ER	0.174	*0.000*
	Per Capita GDP	0.408	*0.000*
	Per Capita GDP^2	-0.002	*0.000*
	$\overline{\text{HRST}}$ low-tech	-0.648	*0.000*
	$\overline{\text{HRST}}$ high tech	-0.805	*0.000*
	$\overline{\text{HRST}}$ high tech^2	0.017	*0.000*
	D 1997	-0.595	*0.007*
	D 1998	-0.937	*0.000*
	D Belgium	4.051	*0.000*
	D Greece	2.887	*0.002*
	D Netherlands	2.985	*0.000*
	D Poland	12.095	*0.000*
	D Slovenia	4.654	*0.000*
	Constant	25.412	*0.000*

As regards the focus of this paper a first important outcome is that, once controlling for other possible determinants, sector dynamics of skilled labour are able to affect overall income distribution, and not only wage dispersion. In particular, a growing share of high-skill labour in the low-tech sector (and in the other correlated sectors) is able to reduce income inequality, while a quadratic U-shaped relationship emerges for the high-tech sector (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 – levels of skills being equal – the impact of the industry-specific effects on overall income inequality may be complex, and depend on the share of high-skill labour in the sector, its weight on the total economy, and the sector-by-sector wage differentials. These complex interactions may help to provide tentative explanations of 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 equality 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 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, it 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 wage levels are not directly linked to productivity (for example, 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 pay level. These conjectural interpretations should of course be confirmed by empirical evidence on wage differences among sectors (the skill endowment being equal), which are of course very difficult to obtain due to data shortages.

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 (or only a weak) technological leap occurs, while 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. Put in the dynamic framework described by Atkinsons (2007), this sector specific situation could be represented as a shift of relative skilled labour supply (happening exogenously), which is only partially offset by a movement of relative demand due to technical change. In this case, the "race between technology and education" is reversed (in the sense that supply shifts before demand), and the likely outcomes are decreasing or stable skill premia.

5. Conclusions

Before summing up the main findings of our empirical analysis, it is useful to recall one consideration 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 generalised demand for skilled labour, an unprecedented relationship among new skill-complementary technologies, qualified labour demand and income distribution has been characteristic of 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 answer relies on 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 overall 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 income inequality, in 14 European countries in the period 1995-2001.

This analysis was subdivided into two steps, one estimating the effect of skill-biased technological change in the labour market by sectors of different technology intensity, and the other using the information obtained– that is, skilled labour demand incorporating the effect of technologies, wages and output – as a determinant, together with others, of inequality. Differently from many other studies, our concern is not simply on the effects of SBTC on earnings dispersion, but on the capacity of SBTC in different technology intensive sectors to affect overall income inequality, which also depends on other income sources (capital, self-employment, rent, transfers, etc.) and systemic factors (of economic, demographic and institutional nature).

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 in 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 something 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 in a certain country, 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 with growing wage inequality.

The estimations of the second step highlighted the generalised negative and significant impact on inequality of an increase in skilled labour demand in low-tech sectors. Conversely, in hi-tech sectors, which are closely correlated with 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 less well paid employees will be able to improve 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. 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 sector data on wage differences according to human capital endowment.

In addition, 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 a persistent abundance of skilled labour supply, which decreases skill premia and so curbs wage inequality. In other words, the negative effects on inequality of the growing high-skill share of workers in these sectors 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 equality. This interpretation may be consistent with the empirical evidence proposed by Atkinson (2007), about the dynamics of the upper part of the distribution, with the widespread stronger growth of the top decile, compared with that of the top quartile.

Future developments of the paper, beyond considering wage differences between equally skilled labour in different sectors, will be aimed at considering possible relationships between skilled labour demand and supply evolutions and other income sources. Although further research in these directions 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, in view of the different sectoral consequences in terms of the labour market and inequality outcomes.

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