Skill-Biased Technological Change vs. Capital-Skill Complementarity: Evidence from OECD Countries*

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Abstract

It is generally agreed that skill-biased technological change (SBTC) and capital-skill complementarity (CSC) are the two main driving forces behind the large increase in the relative demand for skilled labor, which has taken place in most OECD countries during the last couple of decades. However, the different nature of technological change and the composition of capital

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have not been explicitly distinguished in the previous literature.
In this paper we develop a simple framework which distinguishes and separately quantifies the effects of SBTC and CSC on the demand for skilled labor and, drawing on internationally comparable industry-level data for nine OECD countries over the period 1970-2005 from the EUKLEMS dataset, estimate a translog production function with four inputs (ICT and non-ICT capital, and skilled and unskilled labor) and a separate factor-biased technological change, modeled both as time trend and as contribution of ICT on Total Factor Productivity. This model provides us with a complete description of the pattern of substitution between all the input and of the nature of technological change. Our empirical findings suggest that SBTC and CSC evolves very differently over time and across countries, which point to the importance of treating these two factors separately. Moreover, we enlarge our framework considering allocative inefficiency, international trade, labor and product market regulations and trade. We find that these features play an important role.

Key Words:.capital-skill complementarity; skilled-biased technological change; labor and capital composition; inefficiency.

JEL classification: J24; O39; O57.

1 Introduction

Over the past couple of decades, the wage and employment structure has changed dramatically in many OECD countries. In almost all countries the relative supply of skilled labor has increased considerably. Despite this, the relative wage of skilled labor has not deteriorated. Relative wages have even increased in the US and the UK, while most Continental European countries have had more stable wage structures. These changes provide evidence of large shifts in the demand for skilled labor, which have taken place simultaneously with the supply shifts.

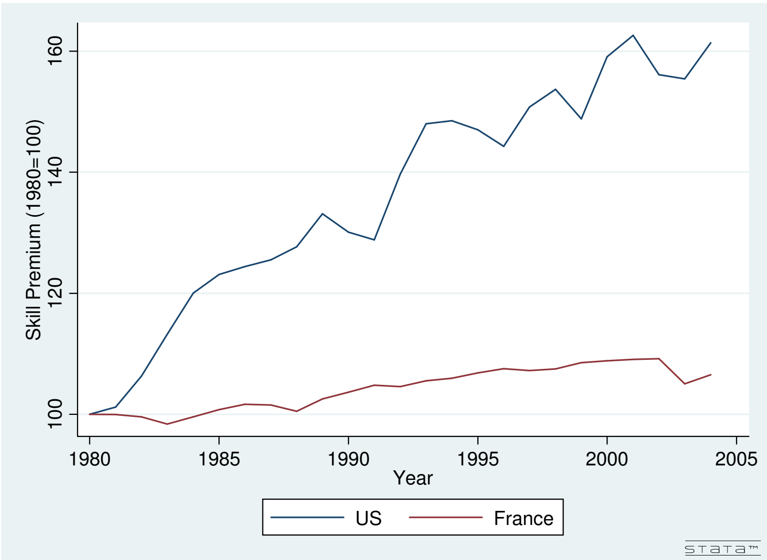

Figure 1: Total Economy: Source: EU KLEMS dataset

Figure 1 shows a comparison between the US and France at the total economy level for the wage skill premium: especially for the period 1980-2000, even if in France the skill premium has increased of about 10%, in the US this phenomenon is much stronger. A large body of literature have agreed that the main driving mechanisms behind these demand shifts are skill-biased technological change (SBTC) and capital-skill complementarity (CSC) (see e.g., Katz and Murphy (1992); Bound and Johnson (1992); Berman, Bound, and Griliches (1994); Johnson (1997); Berman, Bound, and Machin (1998); Machin and van Reenen (1998); Krusell, Ohanian, Rios-Rull, and Violante (2000); Duffy, Papageorgiou, and Perez-Sebastian (2004); Papageorgious and Chmelarova (2005)).[1] Even though both SBTC and CSC generate a higher

[1] Admittedly, other factors such as international trade, labor and product market regulation are also attributed an important role behind these demand shifts (see e.g., Berman, Bound, and Machin (1998), Feenstra and Hanson (2003), Rosholm, Scheuer, and Soerensen (2007), Acemoglu (2003),

relative demand for skilled labor, their underlying nature is somewhat different. SBTC is related to changes in unobservable factors and provides information on how technology affects the relative efficiency of inputs in the production process, while CSC is related to changes in observable factors and elicits information on which inputs in the production process that can be easily substituted/complemented. Although a distinction between SBTC and CSC thus has obvious importance, only one attempt (Ruiz-Arranz (2003)) has been made to separate the effect of SBTC and CSC on the demand for skilled labor in the existing literature.

In this paper we propose a simple framework which distinguishes and separately quantifies the effects of SBTC and CSC on the demand for skilled labor and apply it to industry-level data for nine OECD countries from 1970 onwards. In particular, we present empirical findings of the effect of factor non-neutral technological change and different types of capital on the demand for skilled labor.

To analyze the separate impact of SBTC and CSC on labor demand, we estimate a translog production function with four inputs and a separate variable for the factor-biased technological change. We distinguish between two types of capital, ICT and non-ICT capital, and two types of labor, unskilled and skilled labor. This framework provide us with a complete description of the pattern of substitution between these four inputs and of the nature of technological change. Furthermore, this framework allow technology to be non-neutral, implying that technological change might affect the absolute efficiency of various inputs differently.

Our empirical analysis is based on the so-called EUKLEMS database, which has recently become available. The EUKLEMS database contains internationally comparable data on productivity, capital formation and labor creation at the industry-level for a large number of countries from 1970 onwards. The EUKLEMS database combine at least four key advantages relative to the data that have been used in previous studies on the relationship between skill-structure, technological change and capital equipment. Firstly, the EUKLEMS database have been compiled by national EUKLEMS consortium members, typically in cooperation with National Statistical Office, using a harmonized methodology. Second, the EUKLEMS database covers a large number of countries, industries and years. Third, the EUKLEMS data contains detailed information on employment levels and wages for different educational categories. Finally, the EUKLEMS database contains data on both non-ICT-capital

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Acemoglu (2003) and Alesina and Zeira (2006)). In section 5, we extent our basic framework and examine the effects of these factors on the demand for skilled labor.

and ICT-capital.

We perform our analysis for nine OECD countries: two Anglo-Saxon countries (US and UK), three Nordic countries (Denmark, Finland and Netherlands) and four Continental European countries (Austria, Germany, France and Italy).

Our empirical findings thereby establish that SBTC and CSC evolves differently over time and across countries, which points to the importance of distinguishing explicitly between these two mechanisms.

The rest of the paper is organized as follows: In section 2, we present the production function framework used to analyze the demand for skilled labor. In section 3, we describe the data used in our empirically analysis. In section 4, we present our results with two different representations of technical change, while in section 5 we test the robustness of our findings by examining the effects of international trade and labor and product market regulation on the demand for skilled labor. In section 6, we decompose the growth rate of the relative skill-premium. In section 7 we conclude.

2 The Production Function Framework

To analyze the separate impact of SBTC and CSC on labor demand, we employ a translog (or transcendental logarithmic) production function, introduced by Christensen, Jorgenson, and Lau (1973). The translog production function framework is appropriate to use in order to answer the research questions in this paper, as it overcomes all the limitations of more widely used production functions, such as CES and Cobb-Douglas. First, in the translog specification substitution elasticities are allowed to vary over time, which helps to understand the historical variation in the demand for labor. Second, both substitutability and complementarity between inputs are allowed. Finally, elasticities of substitution are not constrained to be the same, which allows for tests of CSC.

2.1 The Translog Production Function

This section accurately follows the econometric methodology for price behavior suggested by Jorgenson (1986), considering the presence of ICT capital. For finding the skilled-biased technological change and the capital skill complementarity, we estimate the response of the shares of the production function and the rate of the technological change to change in inputs and level of technology under linear and non linear restrictions derived from the theory of labour demand. As mentioned above, we base our analysis on the translog production function, which can be defined as a second-ordered Taylor's series approximation in logarithm to an arbitrary production function. In our case, output Y, represented by value added, is a function of the two types of capital, ICT and non-ICT capital, and the two types of labor, skilled and unskilled labor. For industry $j = 1, \ldots, J$:

$$Y_j = f\left(K_j^{ICT}, K_j^{NICT}, N_j^S, N_j^U\right) \tag{1}$$

Assuming constant return to scale, the value added can be expressed as the sum of the value of the four inputs:

$$P_{Y_t} Y_{jt} = P_{K_{jt}^{ICT}} K_{jt}^{ICT} + P_{K_{jt}^{NICT}} K_{jt}^{NICT} + P_{N_{jt}^S} N_{jt}^S + P_{N_{jt}^U} N_{jt}^U \tag{2}$$

Following Samuelson (1954) and Jorgenson (2001), we prefer working with price function, i.e.

$$P_{Y_t} = p\left(P_{K_j^{ICT}}, P_{K_j^{NICT}}, P_{N_j^S}, P_{N_j^U}, t\right) \tag{3}$$

so the general price function will take the following form

$$\ln P = \alpha_0 + \alpha_p^{'} \ln p + \frac{1}{2} \ln p^{'} B_{pp} \ln p + \ln p^{'} B_{pp} t + f_t \tag{4}$$

where $P = P_{Y_t}$ is the price of output, $p = \begin{bmatrix} P_{K_j^{ICT}} \\ P_{K_j^{NICT}} \\ P_{N_j^S} \\ P_{N_j^U} \end{bmatrix}$ is a vector of input price and the matrix B_{pp} represents the substitution/complementarity among the inputs, the vector B_{pt} represents the nature of the technological change, while the latent variable f_t represents the technological change which is modeled as[2]

$$f_t = \alpha_t t \tag{5}$$

[2] The original form should be $f_t = \alpha_t t + \frac{1}{2} B_{tt} t^2$. With this assumption, we assume....In our case we impose the elements of the matrix B_{tt} to be equal to 0.

Under the assumption of competitive markets for output and all the inputs, we differentiate eq.(5) with respect to the log of the prices and define a system of simultaneous equations expressing the shares as a function of the input price and technology, which appear jointly in the price function

$$v = \frac{\partial \ln P}{\partial \ln p} = \alpha_p + B_{pp} \ln p + B_{pt} t \tag{6}$$

where $v = \begin{bmatrix} v_{K_j^{ICT}} \\ v_{K_j^{NICT}} \\ v_{N_j^S} \\ v_{N_j^U} \end{bmatrix}$ and $B_{pp} = \frac{\partial \ln v}{\partial \ln p} = \frac{\partial^2 \ln P}{\partial \ln p^2} = \begin{bmatrix} \beta_{ss} & \beta_{su} & \beta_{si} & \beta_{sn} \\ \beta_{us} & \beta_{uu} & \beta_{ui} & \beta_{un} \\ \beta_{is} & \beta_{iu} & \beta_{ii} & \beta_{in} \\ \beta_{ns} & \beta_{nu} & \beta_{ni} & \beta_{nn} \end{bmatrix}$

The constant return to scale implies that the sum of the value share for all inputs sum to unity:

$$i'v = i' \frac{\partial \ln P}{\partial \ln p} = 1 \tag{7}$$

where i is the identity vector. Moreover, the production function has the following properties:

1. **Positivity.** The price of the inputs are positive if and only if the price index is positive:

$$p_i > 0 \Leftrightarrow P_i > 0 \tag{8}$$

2. **Integrability.** The price index is homogeneous of degree 0 in input prices, i.e.

$$B_{ppi} = 0 \tag{9}$$

and

$$B_{pti}^{'} = 0 \tag{10}$$

3. **Product Exhaustion.** The sum of the value shares is equal to unity:

$$\alpha_{p'i} = 0 \tag{11}$$

$$B_{ppi}^{'} = 0 \tag{12}$$

$$B_{pti}^{'} = 0 \tag{13}$$

4. **Symmetry.** The share elasticities, the biases and the deceleration of technological change must be symmetric.

$$\begin{bmatrix} B_{pp} & B_{pt} \\ B_{p't} & B_{tt} \end{bmatrix} = \begin{bmatrix} B_{pp} & B_{p't} \\ B_{pt} & B_{tt} \end{bmatrix} \tag{14}$$

5. **Nonnegativity.** The value of the shares must be nonnegative:

$$\frac{\partial \ln q}{\partial p} = \alpha_p + B_{pp} \ln p + B_p t \geq 0 \tag{15}$$

6. **Monotonicity.** The matrix of share elasticities must be nonpositive definite. A sufficient condition is that the matrix $B_{pp} + vv' - V$ where V is the vector of the shares is nonpositive definite. A common way is to decompose the matrix of constant share elasticities B_{pp} in terms of its Choleski factorization:

$$B_{pp} = \begin{bmatrix} \delta_1 & \lambda_{21}\delta_1 & \dots & \lambda_{J1}\delta_1 \\ \lambda_{21}\delta_1 & \lambda_{21}\lambda_{21}\delta_1 + \delta_2 & \dots & \lambda_{J1}\lambda_{21}\delta_1 + \lambda_{J2}\delta_2 \\ \vdots & \vdots & & \vdots \\ \lambda_{J1}\delta_1 & \lambda_{J1}\lambda_{21}\delta_1 + \lambda_{J2}\delta_2 & \dots & \lambda_{J1}\lambda_{J1}\delta_1 + \lambda_{J2}\lambda_{J2}\delta_2 + \dots + \delta_J \end{bmatrix} \tag{16}$$

with $T = \begin{bmatrix} 1 & 0 & \dots & 0 \\ \lambda_{21} & 1 & \dots & 0 \\ \vdots & \vdots & & \vdots \\ \lambda_{J1} & \lambda_{J2} & \dots & 1 \end{bmatrix}$ and $D = \begin{bmatrix} \delta_1 & 0 & \dots & 0 \\ 0 & \delta_2 & \dots & 0 \\ \vdots & \vdots & & \vdots \\ 0 & 0 & \dots & \delta_J \end{bmatrix}$

The Cholesky factorization must satisfy the following conditions:

$$\begin{aligned} 1 + \lambda_{21} + \lambda_{31} + \dots + \lambda_{J1} &= 0, \\ 1 + \lambda_{32} + \lambda_{42} + \dots + \lambda_{J2} &= 0, \\ &\vdots \\ \delta_J &= 0 \end{aligned} \tag{17}$$

Adding a random stochastic component to the equations , for the value shares and the technical change, we can derived the stochastic specifications:

$$\begin{cases} v^i = \alpha_p + B_{pp} \ln p_{pt} t + \epsilon^i \\ \ln P = \alpha_0 + \alpha_p' \ln p + \alpha_t t + \frac{1}{2} \ln p' B_{pp} \ln p + \ln p' B_{pt} t + \frac{1}{2} B_{tt} t^2 + \epsilon_t \end{cases}$$

Eq. (7) implies that the random shocks corresponding to the 4 cost shares sum to zero for each unit:

$$i^{'}\epsilon_k = 0\,(k = ICT, NICT, S, L) \tag{18}$$

letting the errors not distributed independently. Another assumption is that disturbance have covariance matrix that is identical for all producing units and has rank J, where

$$V \begin{bmatrix} \epsilon_{11} \\ \epsilon_{12} \\ \vdots \\ \epsilon_{1K} \\ \epsilon_{21} \\ \vdots \\ \epsilon_{1K} \end{bmatrix} = \Sigma \otimes I$$

where $\Sigma = \begin{bmatrix} \epsilon^t \\ \epsilon^t_t \end{bmatrix}$, with rank J, is the covariance matrix of the random disturbances corresponding to the value shares and the rate of the technical change.

2.2 Technological Change and Autocorrelation of the Error

The unobservable rate of technical change is assumed to be

$$-\,\bar{v}^t_t = \alpha_t + \beta^{'}_{pt}\ln\bar{p}_t + \beta_{tt}\bar{t} + \tilde{\epsilon}^t_t \tag{19}$$

where $\tilde{\epsilon}^t_t = \frac{1}{2}\left[\epsilon^t_t + \epsilon^{t-1}_t\right]$

The covariance matrix of the average is proportional to the Laurent matrix

$$\Omega = \begin{bmatrix} \frac{1}{2} & \frac{1}{4} & 0 & \dots & 0 \\ \frac{1}{4} & \frac{1}{2} & \frac{1}{4} & \dots & 0 \\ 0 & \frac{1}{4} & \frac{1}{2} & \dots & 0 \\ \vdots & \vdots & & & \vdots \\ 0 & 0 & 0 & \dots & \frac{1}{2} \end{bmatrix}$$

$$V \begin{bmatrix} \bar{\epsilon}_t^2 \\ \bar{\epsilon}_t^3 \\ \vdots \\ \bar{\epsilon}_t^T \end{bmatrix} \tilde{\Omega} \tag{20}$$

Since Ω is known and positive definitive, we can calculate the Choleski factorization of the inverse matrix Ω^{-1}:

$$\Omega^{-1} = TDT' \tag{21}$$

where T is a unit lower triangular matrix, D is a diagonal matrix with positive elements along the main diagonal and $P = D^{\frac{1}{2}T'}$. Since $P' = D^{\frac{1}{2}}T'\Omega\left(D^{\frac{1}{2}}T'\right)' = I$, the equations with uncorrelated random disturbances are

$$D^{\frac{1}{2}}T' \begin{bmatrix} \bar{v}_t^2 \\ \bar{v}_t^3 \\ \vdots \\ \bar{v}_t^T \end{bmatrix} = D^{\frac{1}{2}}T' \begin{bmatrix} 1 & \ln \bar{p}_{12} & \dots & 2-\frac{1}{2} \\ 1 & \ln \bar{p}_{13} & \dots & 3-\frac{1}{2} \\ \vdots & \vdots & & \vdots \\ 1 & \ln \bar{p}_{1T} & \dots & T-\frac{1}{2} \end{bmatrix} \begin{bmatrix} \alpha_t \\ \beta_{1t} \\ \vdots \\ \beta_{tt} \end{bmatrix} + D^{\frac{1}{2}}T' \begin{bmatrix} \bar{\epsilon}_t^2 \\ \bar{\epsilon}_t^3 \\ \vdots \\ \bar{\epsilon}_t^T \end{bmatrix} \tag{22}$$

2.3 Parameter Estimation

We are interested in the estimation of the following parameters:

- **share elasticities** B_{pp} which give the response of the value shares of all inputs to proportional changes in the input prices as

$$\begin{cases} \beta_{ij} > 0 & \Leftrightarrow \quad \text{v}_{ij} \text{ increases with the input prices} \\ \beta_{ij} < 0 & \Leftrightarrow \quad \text{v}_{ij} \text{ decreases with the input prices} \end{cases}$$

- the **Price elasticities**

$$\epsilon_{jk} = \frac{\partial \ln q_j}{\partial \ln p_k} = \frac{p_k}{q_j}\frac{\partial q_j}{\partial p_k} \tag{23}$$

- the **Allen partial elasticities** of substitution between factor j and k when $j \neq k$ as the elasticity computed by eq.(23) divided by the share k, i.e.

$$\sigma_{jk} = \frac{\beta_{jk} + v_j v_k}{v_j v_k} = \frac{\epsilon_{jk}}{v_k} \tag{24}$$

and, when $j = k$

$$\sigma_{jj} = \frac{\beta_{jk} + v_j^2 - v_j}{v_j^2} = \frac{\epsilon_{jj}}{v_j} \tag{25}$$

If $\sigma_{jk} > 0$ the factor are substitutes, otherwise the factor are complements. Following Chambers (1988), we define the Morishima elasticities as

$$\sigma_{ij}^M = \epsilon_{ij} - \epsilon_{jj} \tag{26}$$

The Morishima Elasticities give an exact measure of how the i, j input ratio responds to change in w_j.

- **The biases of technical change**, i.e. the double differentiation with respect to the logarithm of input prices and the level of technology:

$$\beta_{pt} = \frac{\partial v}{\partial t} = \frac{\partial^2 \ln P}{\partial \ln p \partial t} = \begin{pmatrix} \beta_{st} \\ \beta_{mt} \\ \beta_{ut} \\ \beta_{nt} \end{pmatrix} \tag{27}$$

the effects of the biases of technical change are the following

$$\begin{cases} \beta_{pt} > 0 & \Leftrightarrow \quad \mathrm{v}_{ij} \text{ increases } (\textit{input-using technology}) \\ \beta_{pt} < 0 & \Leftrightarrow \quad \mathrm{v}_{ij} \text{ decreases } (\textit{input-saving technology}) \end{cases}$$

3 Data

The data we use in our analysis are drawn from the EUKLEMS database, which contains internationally comparable information on productivity, capital formation and employment creation at the industry level for European member states, as well as US and Japan from 1970 onwards. For a detailed description of the EUKLEMS data, see Timmer, van Moergastel, Stuivenwold, Ypma, OMahony, and Kangasniemi (2007).

In our empirical analysis, we divide labor into two types: unskilled and skilled labor. In general, unskilled labor is defined as those workers who have at most completed lower secondary school, while skilled labor is defined as all workers with an educational attainment above lower secondary school. To take into account that the productivity of different types of labor might differ, all labor inputs and price series are quality adjusted, following the approach of Jorgenson, Gollop, and Fraumeni (1987).

Capital is divided into non-ICT-capital and ICT-capital. ICT-capital consist of three main categories: computing equipment, software and communication equipment.

Ideally, the EUKLEMS dataset would cover all countries from 1970 onwards, but due to data limitations, the coverage differs across countries, industries and variables. In turn, we limit our sample to countries where all the relevant variables are available. Furthermore, we restrict our sample to countries having the same industry coverage. Moreover, we limit our sample to the private sector of the economy. This produces an unbalanced sample with eleven countries, consisting of the US, UK, Denmark, Finland, Netherlands, Germany, Austria, France and Italy. Appendix X provides an overview of our sample. (missing at the moment)

To examine the impact of international trade, labor and product market regulation on labor demand, we draw on other databases as the EUKLEMS database does not contain any information on these subjects. To examine the effect of international trade, we use the OECD Bilateral Trade Database. To analyze the effect of labor market regulation, we apply the FRDB Social Reforms Database, which distinguish between the direction (i.e. reduce or increase generosity) and the scope (i.e. marginal or radical) of a labor market reform. Finally, to examine the impact of product market regulation, we employ the dataset constructed by Nicoletti, Scarpetta, and Boylaud (2000).

3.1 Descriptive statistics

To be added.

4 Results

In this section we present our empirical results. We start by presenting the basic results our analysis, assuming that the time trend is a proxy of technical change. We then introduce the ICT TFP contribution at the industry level as an alternative measure of technical change and present the results from that analysis.

4.1 Technical Change modeled as a Time Trend

In this model, we describe aggregate output as a function of four inputs - skilled and unskilled labor, and ICT and non-ICT capital - and separate trends for the factor biases of technological change, which are measured as the time trend. Ruiz-Arranz (2003) also applies this representation of technical changes.

For each country, we use our industry-level data to estimate four equations jointly, three value shares and the translog price function. Each equation also incorporates industry-dummies to control for industry-specific time trends. Below we report the estimates of the full model for each country separately, including Allen and Morishima elasticitities. For the US, we also present Allen elasticities with their corresponding confidence intervals.

We start by looking at the estimated biases of technological change. Overall, it is seen that the effect of technical change on the efficiency of the various inputs is very heterogeneous both within and across countries. In the UK and the US, we find a positive trend of skilled labor bias of technology and a negative trend of unskilled labor bias of technology. This suggests that technical changes are strongly skill-biased in these two countries. In contrast, we see the exact opposite picture in Germany, France and Italy, namely that technical changes favors the use of unskilled labor relative to skilled labor. In Austria, Denmark, Finland and Netherlands the picture is more mixed. Here we find that technical changes mitigate both the use of skilled and unskilled labor.

Turning to capital-biases of technical change, we find that technical changes favor the use of non-ICT capital in all countries. A little surprising, we find a negative trend of ICT-capital bias of technology in all countries, except Denmark and the UK In the UK, we find a significant positive trend, while it is positive, but insignificant in Denmark. This suggests that technical changes favor the use of non-ICT capital relative to ICT capital in all countries, except in the UK, where it increases the use of all types of capital.

Now we turn to the substitution between inputs, which is given by the Allen and Morishima elasticities. At the moment, we have only commented on the

Allen elasticities. Our findings reveals how differently ICT capital and non-ICT capital interact with skilled labor in the production function. Griliches (1969) hypothesis to test ICT-skill complementarity is $H_o : \sigma_{si} = \sigma_{ui}$ against $H_o : \sigma_{si} < \sigma_{ui}$. In all of the nine countries, we find that the null hypothesis is rejected and, in turn, this suggests that ICT capital-skill complementarity is present in all of the countries. Furthermore, we find non-ICT capital-skill substitution in all countries, except Denmark and Finland. In these two countries, non-ICT capital and skilled labor is complementary. In general, our findings suggest that the large increase in the stock of ICT capital, which has been triggered by its decline in price, has come along with a large demand for its complementary labor input (skilled labor) and a reduction in the demand for its substitutable labor input (unskilled labor).

4.1.1 Austria

Table 1: Estimation results.

	Skilled	Unskilled	ICT	NICT
Skilled	0.030***			
	(0.01)			
Unskilled	-0.005	0.166***		
	(0.01)	(0.01)		
ICT	-0.017***	0.034***	-0.010***	
	(0.00)	(0.00)	(0.00)	
NICT	-0.008***	-0.195***	-0.006***	0.209***
	(0.00)	(0.00)	(0.00)	(0.00)
β_t	-0.000***	-0.000	-0.000***	0.000***
	(0.00)	(0.00)	(0.00)	(0.00)
N obs				600
N industries				24

Significance levels : $*$: 10% $**$: 5% $***$: 1%

Table 2: Allen Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	-5.9300			
Unskilled	0.8160	-0.1874		
ICT	-13.1200	2.9435	-47.9030	
NICT	0.3633	-0.0400	0.2813	-0.0288

Table 3: Morishima Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	0.0000	1.6899	8.7e+06	1.5e+05
Unskilled	-6.2e+03	0.0000	9.0e+06	1.5e+05
ICT	-1.0e+04	17.7360	0.0000	1.5e+05
NICT	-6.3e+03	0.2050	1.0e+08	0.0000

4.1.2 Denmark

Table 4: Estimation results

	Skilled	Unskilled	ICT	NICT
Skilled	-0.013			
	(0.01)			
Unskilled	0.043***	0.098***		
	(0.01)	(0.01)		
ICT	-0.009***	-0.038***	-0.060***	
	(0.00)	(0.00)	(0.00)	
NICT	-0.022***	-0.103***	0.107***	0.018***
	(0.00)	(0.00)	(0.00)	(0.00)
β_t	-0.000***	-0.000***	0.000	0.000***
	(0.00)	(0.00)	(0.00)	(0.00)
N obs				599
N industries				24

Significance levels : $*$: 10% $**$: 5% $***$: 1%

Table 5: Allen Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	-48.1853			
Unskilled	3.3111	-0.3169		
ICT	-8.0704	-0.8241	-86.7203	
NICT	-1.6188	0.4529	12.2788	-2.2162

Table 6: Morishima Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	0.0000	96.2433	9.7e+05	-1.4e+03
Unskilled	1.7e+04	0.0000	9.7e+05	-1.0e+03
ICT	1.3e+04	-28.9572	0.0000	-1.0e+03
NICT	1.5e+04	-10.8834	3.7e+06	0.0000

4.1.3 Finland

Table 7: Estimation results

	Skilled	Unskilled	ICT	NICT
Skilled	0.102***			
	(0.02)			
Unskilled	-0.039**	0.048***		
	(0.01)	(0.01)		
ICT	-0.046***	0.031***	-0.074***	
	(0.00)	(0.00)	(0.00)	
NICT	-0.017***	-0.040***	0.089***	-0.032***
	(0.00)	(0.00)	(0.00)	(0.00)
β_t	-0.000***	0.000***	-0.000***	0.000***
	(0.00)	(0.00)	(0.00)	(0.00)
N obs				600
N industries				24

Significance levels : $*$: 10% $**$: 5% $***$: 1%

Table 8: Allen Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	-1.3834			
Unskilled	0.5566	-0.8139		
ICT	-9.2696	3.4448	-1.5e+02	
NICT	0.6774	0.7306	12.5447	-2.6820

Table 9: Morishima Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	0.0000	3.4028	3.4e+08	-5.9e+05
Unskilled	-30.2495	0.0000	3.4e+08	-5.9e+05
ICT	-4.8e+02	31.0340	0.0000	-5.9e+05
NICT	-25.9683	5.4283	3.9e+08	0.0000

4.1.4 France

Table 10: Estimation results

	Skilled	Unskilled	ICT	NICT
Skilled	0.075***			
	(0.01)			
Unskilled	-0.038***	0.119***		
	(0.01)	(0.01)		
ICT	-0.049***	0.029***	-0.069***	
	(0.00)	(0.00)	(0.00)	
NICT	0.012***	-0.110***	0.090***	0.008
	(0.00)	(0.00)	(0.00)	(0.01)
β_t	-0.000***	0.000***	-0.000***	0.000***
	(0.00)	(0.00)	(0.00)	(0.00)
N obs				600
N industries				24

Significance levels : $*$: 10% $**$: 5% $***$: 1%

Table 11: Allen Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	0.2115			
Unskilled	0.2228	-0.3248		
ICT	-21.9020	2.7555	-1.3e+02	
NICT	1.5361	0.3482	13.0761	-2.5019

Table 12: Morishima Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	0.0000	0.5445	4.8e+06	-3.6e+04
Unskilled	-4.2e+02	0.0000	4.9e+06	-3.7e+04
ICT	-1.5e+03	8.1338	0.0000	-3.7e+04
NICT	-3.7e+02	0.7555	-6.3e+08	0.0000

4.1.5 Germany

Table 13: Estimation results

	Skilled	Unskilled	ICT	NICT
Skilled	0.086***			
	(0.01)			
Unskilled	-0.062***	0.102***		
	(0.01)	(0.01)		
ICT	-0.022***	-0.000	-0.007*	
	(0.00)	(0.00)	(0.00)	
NICT	-0.002***	-0.040***	0.029***	0.013***
	(0.00)	(0.00)	(0.00)	(0.00)
β_t	-0.000***	0.000***	-0.000***	0.000***
	(0.00)	(0.00)	(0.00)	(0.00)
N obs				331
N industries				24

Significance levels : $*$: 10% $**$: 5% $***$: 1%

Table 14: Allen Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	7.5222			
Unskilled	-0.4438	-0.2246		
ICT	-19.0833	0.9866	-75.8353	
NICT	0.8418	0.7416	8.2651	-3.2015

Table 15: Morishima Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	0.0000	-2.9680	1.9e+09	-1.2e+06
Unskilled	-1.8e+03	0.0000	1.9e+09	-1.2e+06
ICT	-2.9e+03	2.4363	0.0000	-1.2e+06
NICT	-1.7e+03	2.0827	2.6e+09	0.0000

4.1.6 Italy

Table 16: Estimation results

	Skilled	Unskilled	ICT	NICT
Skilled	0.012**			
	(0.00)			
Unskilled	0.004	0.113***		
	(0.00)	(0.01)	ICT	-0.016***
-0.002	-0.036***			
	(0.00)	(0.00)	(0.00)	
NICT	0.000	-0.115***	0.055***	0.060***
	(0.00)	(0.01)	(0.00)	(0.01)
β_t	-0.000***	0.000***	-0.000***	0.000***
	(0.00)	(0.00)	(0.00)	(0.00)
N obs				595
N industries				24

Significance levels : $*$: 10% $**$: 5% $***$: 1%

Table 17: Allen Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	-20.6813			
Unskilled	1.2597	-0.2373		
ICT	-18.2715	0.8937	-57.5843	
NICT	1.0538	0.3648	6.8379	-1.8885

Table 18: Morishima Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	0.0000	3.5967	-5.0e+09	1.2e+04
Unskilled	-1.1e+04	0.0000	-5.0e+09	1.2e+04
ICT	2.9e+04	2.3086	0.0000	1.2e+04
NICT	-1.1e+04	1.4131	-5.0e+09	0.0000

4.1.7 The Netherlands

Table 19: Estimation results

	Skilled	Unskilled	ICT	NICT
Skilled	0.011			
	(0.01)			
Unskilled	0.063***	0.024*		
	(0.01)	(0.01)		
ICT	-0.058***	0.012***	-0.066***	
	(0.00)	(0.00)	(0.00)	
NICT	-0.017***	-0.100***	0.112***	0.005
	(0.00)	(0.00)	(0.00)	(0.00)
β_t	-0.000***	-0.000**	-0.000***	0.000***
	(0.00)	(0.00)	(0.00)	(0.00)
N obs				624
N industries				24

Significance levels : $*$: 10% $**$: 5% $***$: 1%

Table 20: Allen Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	-5.7534			
Unskilled	1.8825	-0.8027		
ICT	-13.1166	1.7635	-1.0e+02	
NICT	0.5824	0.3641	13.4801	-2.3329

Table 21: Morishima Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	0.0000	411.4617	-1.1e+09	1.9e+04
Unskilled	1.0e+03	0.0000	-1.1e+09	1.9e+04
ICT	-5.7e+02	37.5978	0.0000	1.9e+04
NICT	-2.4e+02	-2.5676	-6.8e+08	0.0000

4.1.8 United Kingdom

Table 22: Estimation results

	Skilled	Unskilled	ICT	NICT
Skilled	0.051***			
	(0.01)			
Unskilled	-0.017	0.034***		
	(0.01)	(0.00)		
ICT	-0.030***	-0.018***	0.034***	
	(0.00)	(0.00)	(0.00)	
NICT	-0.003*	0.014***	-0.070***	0.059***
	(0.00)	(0.00)	(0.00)	(0.00)
β_t	-0.000***	-0.000***	0.000***	0.000***
	(0.00)	(0.00)	(0.00)	(0.00)
N obs				672
N industries				24

Significance levels : $*$: 10% $**$: 5% $***$: 1%

Table 23: Allen Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	-2.7921			
Unskilled	0.5986	-0.4681		
ICT	-12.7721	2.6758	-47.1441	
NICT	0.8265	0.5944	2.6116	-1.8447

Table 24: Morishima Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	0.0000	-0.9594	3.6e+06	1.1e+10
Unskilled	-1.3e+05	0.0000	3.7e+06	1.1e+10
ICT	-1.6e+05	19.7561	0.0000	1.1e+10
NICT	-1.3e+05	7.7562	4.2e+06	0.0000

4.1.9 United States

Table 25: Estimation results

	Skilled	Unskilled	ICT	NICT
Skilled	0.075***			
	(0.01)			
Unskilled	-0.038***	0.119***		
	(0.01)	(0.01)		
ICT	-0.049***	0.029***	-0.069***	
	(0.00)	(0.00)	(0.00)	
NICT	0.012***	-0.110***	0.090***	0.008
	(0.00)	(0.00)	(0.00)	(0.01)
β_t	-0.000***	0.000***	-0.000***	0.000***
	(0.00)	(0.00)	(0.00)	(0.00)
N obs				672
N industries				24

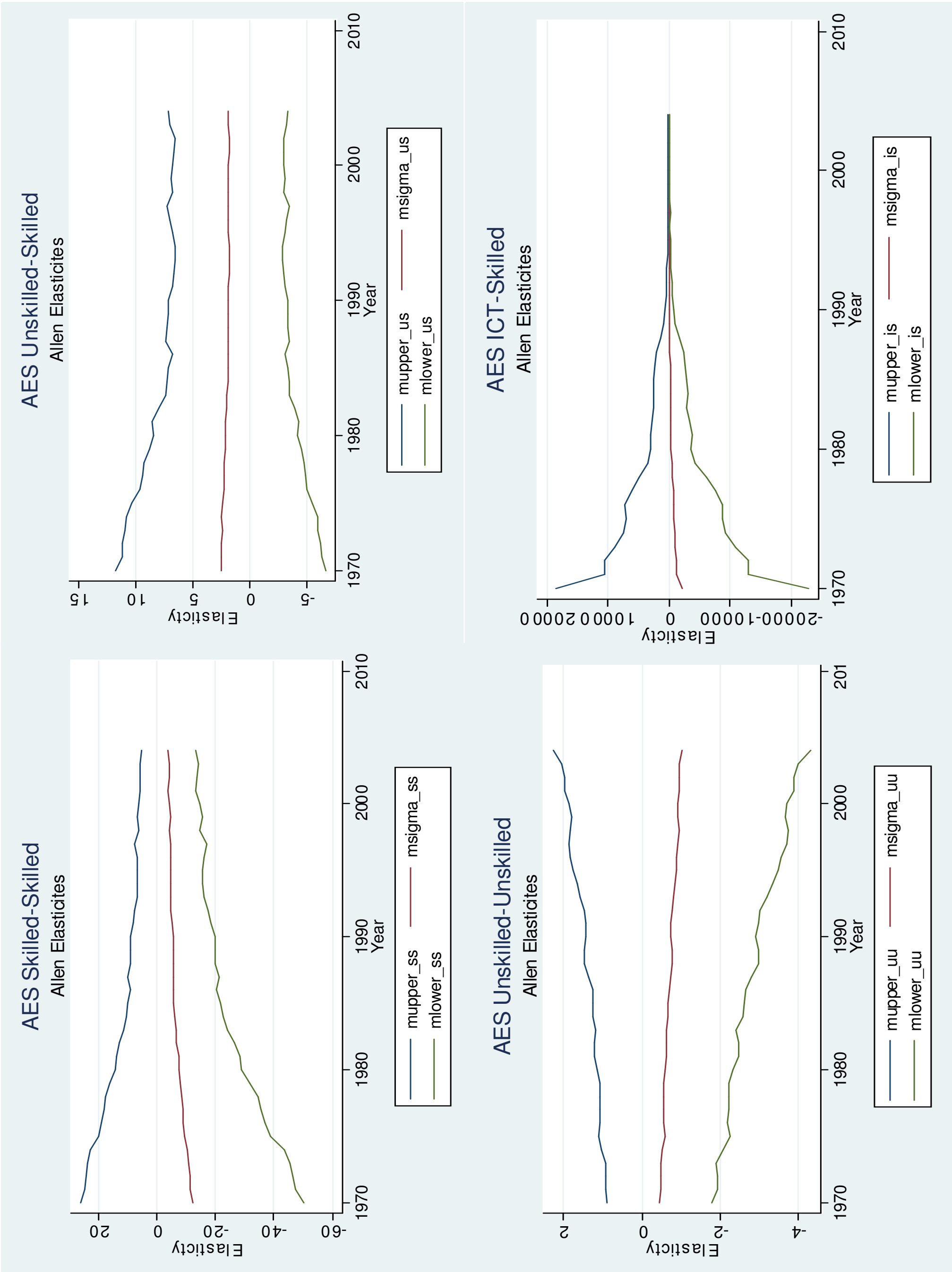
Significance levels : $*$: 10% $**$: 5% $***$: 1%

Table 26: Allen Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	-5.0950			
Unskilled	1.6903	-0.6422		
ICT	-21.2241	0.5278	-1.2e+02	
NICT	1.9411	0.1339	21.0279	-3.2396

Table 27: Allen Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	0.0000	7.6783	8.5e+08	38.4699
Unskilled	91.9142	0.0000	8.6e+08	26.7100
ICT	-1.1e+04	-4.7578	0.0000	26.7100
NICT	96.5996	2.0567	8.6e+08	0.0000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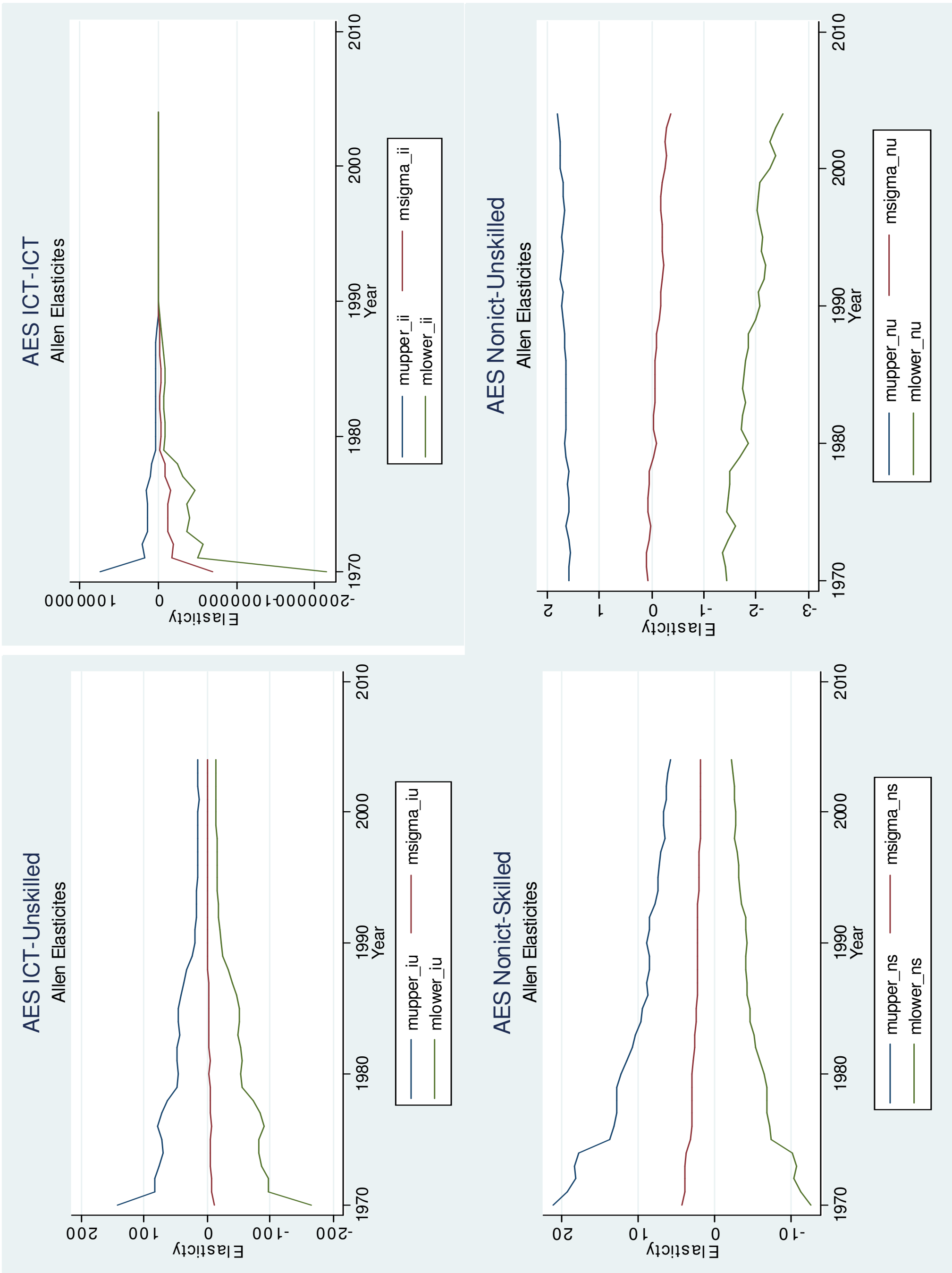
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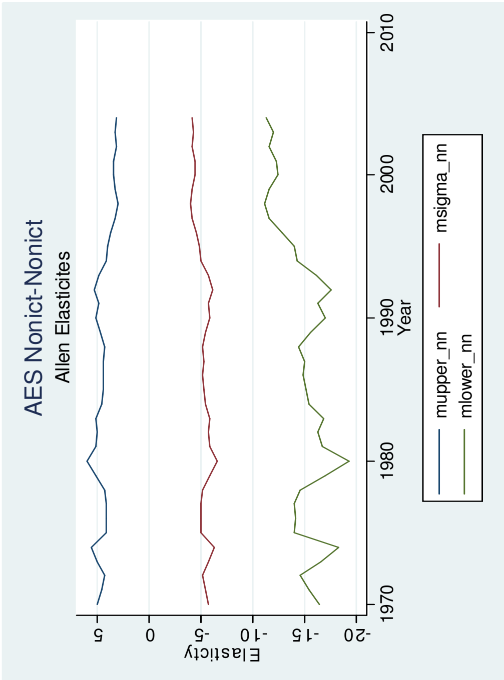
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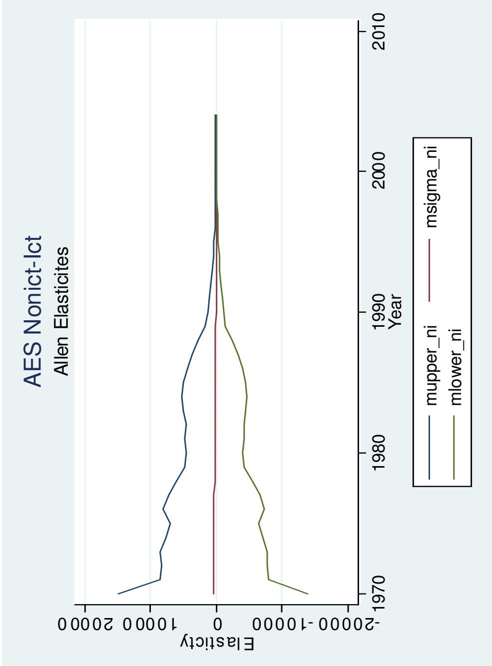
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4.2 Technological Change Represented as ICT TFP

In the previous section we have assumed that the time trend *year* represents the technology level in the economy. As already noted by Chambers (1988) from a theoretical point of view and by Kopp and Smith (1983), Gollop and Roberts (1983) and Baltagi and Griffin (1988) from an empirical perspective, this assumption does not seem realistic since it does not take into account of innovations and developments and the embodiments of the new investment. An analysis related to the ICT contribution to the technological change cannot be performed without considering the important role of productivity and using the methodology and the tools provided by growth accounting.

For these reasons, we detect the ICT TFP contribution following two different approaches: one, introduced by Greenwood, Hercowitz, and Krusell (1997), which exploits the growth accounting with investment-specific technological progress, the other, exposed by Jorgenson, Ho, and Stiroh (2005), which exploits the combination of price decline and use industry level data for computing the ICT TFP at aggregate level.

4.2.1 The Greenwood, Hercowitz and Krusell's Approach

This approach considers Hulten (1992), who reconsiders the production function with neutral A and capital-embodied technological change $q = \frac{1}{p^{ICT}}$. In our case, assuming constant returns to scale and averaging the input shares , aggregating all the types of labor under the term N, we rewrite our production function as

$$Y = AF\left(qK^{ICT}, K^{NICT}, N\right) \tag{28}$$

such as the production relationship in logarithmic difference gives

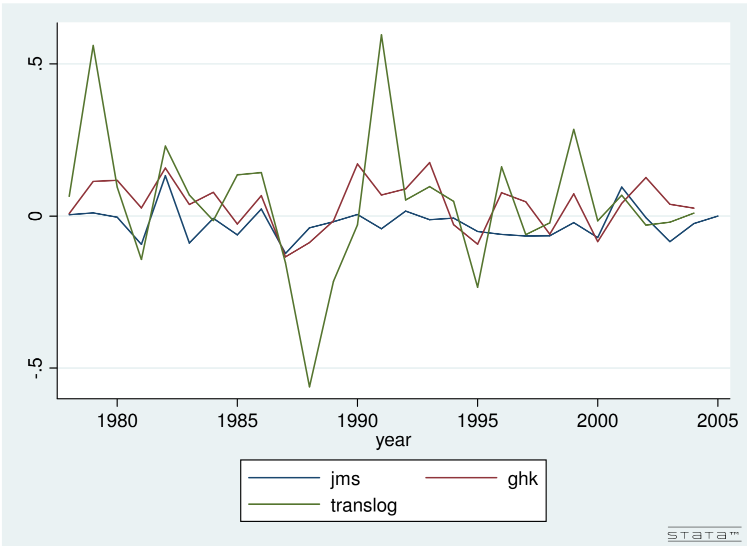
$$\hat{y} = \hat{a} + \bar{\alpha}^{ICT}\hat{q} + \bar{\alpha}^{ICT}\hat{k}^{ICT} + \bar{\alpha}^{NICT}\hat{k}^{NICT} + \left(1 - \bar{\alpha}^{NICT}\right)\hat{n} \tag{29}$$

So, the investment specific technological change to growth will be represented by

$$\frac{\bar{\alpha}^{ICT}\hat{q}}{\bar{\alpha}^{ICT}\hat{q} + \hat{a}} \tag{30}$$

4.2.2 The Jorgenson, Ho and Stiroh's Approach

In this case, the aggregate total factor productivity growth can be defined as the difference between the growth in the price input minus a weighted average of the growth rates of input prices with value shares of the inputs as weights. We expect that the decline in ICT price will dominate. Moreover, following Baltagi and Griffin (1988) we can derive the measure of our nonneutral technical change multiplying the vector price with the coefficient of the technical change, i.e. $\sum i\beta_{ipt} \ln P_i$



Accordingly, we replace the time trend with the ICT TFP contribution at the industry level as a measure of technical change. Beyond this, our model is identical to the one above. Below we report the estimates of the full model for each country separately, including Allen and Morishima elasticitities.

Looking at the estimated labor-biases of technological change, our analysis provides a very ambiguous picture of the effect of technical change on the efficiency of skilled and unskilled labor across countries. In Austria, Denmark and Germany, we find a positive trend of skilled labor bias of technology and a negative or insignificant trend of unskilled labor bias of technology, which suggests that technical changes are strongly skill-biased in these three countries. On the other hand, we find that technical changes favor the use of unskilled labor in the US and the UK Finally, in Finland, France, Netherlands and Italy we find that technical changes decrease the use of both skilled and unskilled labor.

Turning to the capital-biases of technical change, we find that technical changes favor the use of non-ICT capital in all countries, except Austria and the US. In these two countries technical changes is a non-ICT capital-saving technology. Again we find a negative trend of ICT capital-bias of technology in most countries (Denmark, Finland, Germany, Netherlands, UK and Italy), while it is insignificant in the remaining three countries (Austria, France and US). To sum up, we find that estimated biases of technical change have changed dramatically when applying ICT TFP as a measure of technical change instead of the time trend, especially for the labor-biases of technical change. In addition, it seems - as expected - that the ICT TFP has a less significant influence on the efficiency of the four inputs than the time trend. This suggests that the choice of the measure of technical changes is crucial when studying SBTC.

Turning to the substitution between inputs, our analysis paints a very clear picture about the interaction between capital and labor types. For all nine countries, we find evidence of both ICT capital-skill complementarity and non-ICT capital-skill substitution.

4.2.3 Austria

Table 28: Estimation results.

	Skilled	Unskilled	ICT	NICT
Skilled	-0.035***			
	(0.00)			
Unskilled	0.031***	0.199***		
	(0.00)	(0.01)		
ICT	-0.031***	-0.030***	-0.057***	
	(0.00)	(0.00)	(0.00)	
NICT	0.035***	-0.199***	0.118***	0.046***
	(0.00)	(0.00)	(0.00)	(0.00)
ICT TFP	-0.185*	-0.336	-0.313	0.834**
	(0.07)	(0.18)	(0.20)	(0.28)
N obs				600
N industries				24

Significance levels : $*$: 10% $**$: 5% $***$: 1%

Table 29: Allen Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	-41.3143			
Unskilled	2.1676	-0.1002		
ICT	-24.6513	-0.7592	-1.1e+02	
NICT	3.6827	-0.0654	14.8872	-1.7929

Table 30: Morishima Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	0.0000	5.0002	4.7e+07	3.6e+04
Unskilled	1.1e+04	0.0000	4.7e+07	3.4e+04
ICT	3.8e+03	-12.1591	0.0000	3.4e+04
NICT	1.2e+04	-0.0911	5.7e+08	0.0000

4.2.4 Denmark

Table 31: Estimation results.

	Skilled	Unskilled	ICT	NICT
Skilled	-0.012***			
	(0.00)			
Unskilled	-0.001	0.154***		
	(0.00)	(0.00)		
ICT	-0.044***	0.102***	0.117***	
	(0.00)	(0.00)	(0.00)	
NICT	0.057***	-0.254***	-0.174***	0.372***
	(0.00)	(0.00)	(0.00)	(0.00)
ICT TFP	-0.237***	1.057***	0.594**	-1.413***
	(0.06)	(0.15)	(0.19)	(0.26)
N obs				575
N industries				24

Significance levels : $*$: 10% $**$: 5% $***$: 1%

Table 32: Allen Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	-47.1615			
Unskilled	0.9315	-0.1815		
ICT	-45.3613	5.8582	80.7785	
NICT	7.6924	-0.3533	-17.4279	1.9458

Table 33: Morishima Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	0.0000	-24.0745	-1.9e+06	-3.0e+04
Unskilled	1.5e+04	0.0000	-1.8e+06	-3.2e+04
ICT	-1.4e+02	33.8726	0.0000	-3.2e+04
NICT	1.7e+04	-27.2053	-6.9e+06	0.0000

4.2.5 Finland

Table 34: Estimation results.

	Skilled	Unskilled	ICT	NICT
Skilled	-0.019***			
	(0.00)			
Unskilled	0.098***	-0.051***		
	(0.00)	(0.01)		
ICT	-0.027***	0.100***	0.033***	
	(0.00)	(0.00)	(0.00)	
NICT	-0.052***	-0.147***	-0.106***	0.305***
	(0.00)	(0.00)	(0.00)	(0.00)
ICT TFP	0.241***	0.475***	0.603***	-1.320***
	(0.05)	(0.10)	(0.12)	(0.24)
N obs				816
N industries				24

Significance levels : $*$: 10% $**$: 5% $***$: 1%

Table 35: Allen Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	-5.3117			
Unskilled	2.1251	-1.2115		
ICT	-5.0585	8.7736	12.3219	
NICT	0.0055	0.0190	-12.6623	1.0501

Table 36: Morishima Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	0.0000	16.3815	-1.5e+08	5.8e+06
Unskilled	99.3663	0.0000	-1.5e+08	5.8e+06
ICT	-1.9e+02	88.4708	0.0000	5.8e+06
NICT	67.4055	6.7621	-2.1e+08	0.0000

4.2.6 France

Table 37: Estimation results.

	Skilled	Unskilled	ICT	NICT
Skilled	-0.042***			
	(0.00)			
Unskilled	0.063***	0.061***		
	(0.00)	(0.01)		
ICT	-0.043***	0.115***	0.040***	
	(0.00)	(0.00)	(0.00)	
NICT	0.022***	-0.239***	-0.112***	0.328***
	(0.00)	(0.00)	(0.00)	(0.00)
ICT TFP	0.606***	1.650***	0.469	-2.725***
	(0.08)	(0.27)	(0.32)	(0.53)
N obs				816
N industries				24

Significance levels : $*$: 10% $**$: 5% $***$: 1%

Table 38: Allen Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	-18.1019			
Unskilled	2.2987	-0.4822		
ICT	-19.0280	8.0670	18.8295	
NICT	2.0042	-0.4202	-14.0143	1.6635

Table 39: Morishima Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	0.0000	6.8015	-2.8e+06	-1.7e+06
Unskilled	819.7217	0.0000	-2.7e+06	-1.7e+06
ICT	-2.1e+02	25.1328	0.0000	-1.7e+06
NICT	832.8435	-0.9982	3.7e+08	0.0000

4.2.7 Germany

Table 40: Estimation results.

	Skilled	Unskilled	ICT	NICT
Skilled	-0.054***			
	(0.00)			
Unskilled	0.073***	-0.042***		
	(0.00)	(0.01)		
ICT	-0.035***	-0.026***	0.151***	
	(0.00)	(0.01)	(0.01)	
NICT	0.017***	-0.005	-0.090***	0.078***
	(0.00)	(0.00)	(0.00)	(0.00)
ICT TFP	-0.140**	0.157	1.119***	-1.136***
	(0.05)	(0.13)	(0.22)	(0.16)
N obs				816
N industries				24

Significance levels : $*$: 10% $**$: 5% $***$: 1%

Table 41: Allen Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	-29.5738			
Unskilled	2.6937	-0.5214		
ICT	-30.8160	-1.0750	413.9178	
NICT	2.2298	0.9668	-21.3820	-1.9057

Table 42: Morishima Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	0.0000	10.4057	-4.3e+10	-7.1e+06
Unskilled	2.3e+03	0.0000	-4.3e+10	-7.1e+06
ICT	361.3899	-3.0637	0.0000	-7.1e+06
NICT	2.2e+03	3.9824	-4.5e+10	0.0000

4.2.8 Italy

Table 43: Estimation results.

	Skilled	Unskilled	ICT	NICT
Skilled	-0.033***			
	(0.00)			
Unskilled	0.031***	0.029***		
	(0.00)	(0.01)		
ICT	-0.016***	-0.065***	0.390***	
	(0.00)	(0.01)	(0.01)	
NICT	0.018***	0.005	-0.308***	0.285***
	(0.00)	(0.00)	(0.00)	(0.00)
ICT TFP	0.892***	0.532	3.594***	-5.018***
	(0.10)	(0.32)	(0.61)	(0.50)
N obs				578
N industries				24

Significance levels : $*$: 10% $**$: 5% $***$: 1%

Table 44: Allen Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	-98.4474			
Unskilled	2.9391	-0.4238		
ICT	-18.4360	-1.7945	293.6862	
NICT	3.7828	1.0292	-31.8690	1.2172

Table 45: Morishima Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	0.0000	3.5967	-5.0e+09	1.2e+04
Unskilled	-1.1e+04	0.0000	-5.0e+09	1.2e+04
ICT	2.9e+04	2.3086	0.0000	1.2e+04
NICT	-1.1e+04	1.4131	-5.0e+09	0.0000

4.2.9 The Netherlands

Table 46: Estimation results.

	Skilled	Unskilled	ICT	NICT
Skilled	-0.019***			
	(0.00)			
Unskilled	0.041***	0.102***		
	(0.00)	(0.00)		
ICT	-0.037***	0.087***	0.106***	
	(0.00)	(0.00)	(0.00)	
NICT	0.015***	-0.230***	-0.156***	0.372***
	(0.00)	(0.00)	(0.00)	(0.00)
ICT TFP	0.436***	0.775*	1.022*	-2.233**
	(0.11)	(0.32)	(0.40)	(0.68)
N obs				816
N industries				24

Significance levels : $*$: 10% $**$: 5% $***$: 1%

Table 47: Allen Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	-7.4139			
Unskilled	1.5701	-0.5251		
ICT	-7.8894	6.4434	83.1268	
NICT	1.3698	-0.4702	-16.4864	1.8747

Table 48: Morishima Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	0.0000	98.0613	1.8e+09	1.2e+06
Unskilled	2.6e+03	0.0000	1.8e+09	1.2e+06
ICT	1.5e+03	77.5190	0.0000	1.2e+06
NICT	1.8e+03	-1.8e+02	1.1e+09	0.0000

4.2.10 UK

Table 49: Estimation results.

Skilled	-0.027***			
	(0.00)			
Unskilled	0.040***	0.027***		
	(0.00)	(0.01)		
ICT	-0.027***	0.015***	0.002	
	(0.00)	(0.00)	(0.00)	
NICT	0.015***	-0.082***	0.010***	0.058***
	(0.00)	(0.00)	(0.00)	(0.00)
ICT TFP	0.600***	-0.606***	0.541***	-0.534**
	(0.09)	(0.15)	(0.06)	(0.16)
N obs				816
N industries				24

Significance levels : $*$: 10% $**$: 5% $***$: 1%

Table 50: Allen Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	-19.4146			
Unskilled	1.9347	-0.5365		
ICT	-11.4079	1.7605	-27.6895	
NICT	1.7696	0.5244	2.0741	-1.8578

Table 51: Morishima Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	0.0000	15.1964	-5.1e+05	1.1e+10
Unskilled	8.1e+04	0.0000	-4.5e+05	1.1e+10
ICT	5.5e+04	11.7828	0.0000	1.1e+10
NICT	8.2e+04	9.2966	-1.7e+05	0.0000

4.2.11 US

Table 52: Estimation results.

Skilled	-0.021***			
	(0.00)			
Unskilled	0.031***	0.056***		
	(0.00)	(0.01)		
ICT	-0.066***	0.019***	-0.088***	
	(0.00)	(0.00)	(0.00)	
NICT	0.056***	-0.106***	0.135***	-0.085***
	(0.00)	(0.00)	(0.00)	(0.00)
ICT TFP	0.107	-0.857***	-0.350	1.100**
	(0.11)	(0.23)	(0.26)	(0.35)
N obs				816
N industries				24

Significance levels : $*$: 10% $**$: 5% $***$: 1%

Table 53: Allen Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	-6.4244			
Unskilled	1.4079	-0.7890		
ICT	-12.5347	2.1840	-1.2e+02	
NICT	2.1445	0.3306	14.2237	-2.9607

Table 54: Morishima Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	0.0000	7.4149	8.5e+08	36.9020
Unskilled	132.9510	0.0000	8.5e+08	24.6820
ICT	-6.8e+03	29.5885	0.0000	24.6820
NICT	145.6823	3.5989	8.5e+08	0.0000

5 Other Explanations

There are other factors than SBTC and CSC that might affect the demand for skilled labor. In this section, we test the robustness of our key findings by examining the impact of international trade, labor and product market regulation.

5.1 International Trade

Besides SBTC and CSC, increasing international trade is often considered as the main alternative mechanism behind the relative demand shifts towards skilled labor. In this section, we study the effect on the relative demand for skilled labor of exposure to foreign competition.

From standard trade models of comparative advantages we can readily derive the hypothesis that the relative demand for skilled labor in high-wage countries increases with industry exposure to imports from low-wage countries. However, these models do not provide us with any clear predictions about the effect of increasing trade with high-wage countries, as we have no priors as to whether a specific industry in a given high-wage country has comparative advantages in skilled and unskilled labor compared to the same industry in other high-wage countries.

Ideally, we would then obtain the purest measure of foreign competition if we only consider import competition from low-wage countries. At the moment, however, we have only constructed our measure of import competition for all countries together.

To assess the empirical impact of international trade on labor demand, we apply the OECD Bilateral Trade Database and construct a measure of changes in import competition. The variable is constructed as the changes in the ratio of total imports to value added. Machin and van Reenen (1998) also apply this measure of import competition. To investigate whether this variable is correlated with skill-upgrading, we replace our measure of technical change with this variable in our cost-share model. Below we report the estimates of the full model for each country separately below, including Allen and Morishima elasticitities.

5.1.1 Austria

Table 55: Estimation results.

Skilled	-0.054**			
	(0.02)			
Unskilled	-0.025	0.175***		
	(0.02)	(0.02)		
ICT	-0.048***	0.014***	0.014***	
	(0.00)	(0.00)	(0.00)	
NICT	0.127***	-0.163***	-0.163***	0.051***
	(0.01)	(0.00)	(0.00)	(0.01)
Import	0.000	-0.000*	-0.000*	0.000*
	(0.00)	(0.00)	(0.00)	(0.00)
N obs				150
N industries				13

Significance levels : * : 10% ** : 5% * * * : 1%

Table 56: Allen Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	-51.2788			
Unskilled	0.0367	-0.1645		
ICT	-39.8027	1.8364	28.8570	
NICT	10.6562	0.1290	-0.7023	-1.7285

Table 57: Morishima Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	0.0000	-0.0608	-6.2e+07	6.6e+04
Unskilled	2.6e+03	0.0000	-6.1e+07	5.8e+04
ICT	-1.1e+04	8.6028	0.0000	5.8e+04
NICT	3.3e+03	0.4641	-7.4e+08	0.0000

5.1.2 Denmark

Table 58: Estimation results.

Skilled	-0.036***			
	(0.01)			
Unskilled	0.026**	0.064***		
	(0.01)	(0.01)		
ICT	-0.011***	-0.008	0.006*	
	(0.00)	(0.00)	(0.00)	
NICT	0.022***	-0.082***	0.013***	0.047***
	(0.00)	(0.01)	(0.00)	(0.01)
Import	-0.000***	-0.000	-0.000***	0.000***
	(0.00)	(0.00)	(0.00)	(0.00)
N obs				231
N industries				13

Significance levels : $*$: 10% $**$: 5% $***$: 1%

Table 59: Allen Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	-77.5969			
Unskilled	2.3863	-0.3919		
ICT	-11.5012	0.6262	-24.5518	
NICT	3.6339	0.5608	2.4451	-1.8944

Table 60: Morishima Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	0.0000	19.9426	-4.2e+03	1.3e+03
Unskilled	3.2e+04	0.0000	289.5199	975.6095
ICT	2.6e+04	1.1743	0.0000	975.6095
NICT	3.2e+04	2.2381	-1.9e+04	0.0000

5.1.3 Finland

Table 61: Estimation results.

Skilled	-0.115***			
	(0.01)			
Unskilled	0.081***	-0.028		
	(0.01)	(0.02)		
ICT	-0.033***	-0.023*	0.553***	
	(0.00)	(0.01)	(0.01)	
NICT	0.067***	-0.030**	-0.497***	0.459***
	(0.00)	(0.01)	(0.00)	(0.01)
Import	0.000*	0.000	-0.000	-0.000
	(0.00)	(0.00)	(0.00)	(0.00)
N obs				255
N industries				13

Significance levels : $*$: 10% $**$: 5% $***$: 1%

Table 62: Allen Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	-1.7e+02			
Unskilled	5.3261	-0.6219		
ICT	-30.0205	0.0385	378.1454	
NICT	9.0592	0.8398	-45.5384	3.0466

Table 63: Morishima Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	0.0000	57.4614	-3.6e+05	6.5e+03
Unskilled	8.4e+04	0.0000	-3.5e+05	5.7e+03
ICT	7.0e+04	0.7566	0.0000	5.7e+03
NICT	8.5e+04	6.8427	-3.7e+06	0.0000

5.1.4 France

Table 64: Estimation results.

Skilled	-0.099***			
	(0.01)			
Unskilled	0.046***	0.029		
	(0.01)	(0.02)		
ICT	-0.062***	0.086***	0.106***	
	(0.00)	(0.00)	(0.00)	
NICT	0.115***	-0.161***	-0.131***	0.177***
	(0.00)	(0.01)	(0.00)	(0.00)
Import	0.000**	0.000***	-0.000***	-0.000***
	(0.00)	(0.00)	(0.00)	(0.00)
N obs				255
N industries				13

Significance levels : $*$: 10% $**$: 5% $***$: 1%

Table 65: Allen Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	-26.5950			
Unskilled	1.9288	-0.5656		
ICT	-28.3252	6.4151	117.6246	
NICT	6.2012	0.0348	-17.1377	-0.2986

Table 66: Morishima Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	0.0000	5.7111	5.0e+05	39.1443
Unskilled	1.2e+03	0.0000	5.7e+05	-6.5355
ICT	231.2694	19.5294	0.0000	-6.5355
NICT	1.3e+03	1.4908	1.6e+09	0.0000

5.1.5 Germany

Table 67: Estimation results.

Skilled	-0.335***			
	(0.01)			
Unskilled	0.362***	-0.004		
	(0.02)	(0.01)		
ICT	-0.110***	0.435***	0.435***	
	(0.01)	(0.02)	(0.02)	
NICT	0.083***	-0.321***	-0.321***	-0.321***
	(0.00)	(0.00)	(0.00)	(0.00)
Import	-0.000	0.000***	0.000***	0.000***
	(0.00)	(0.00)	(0.00)	(0.00)
N obs				210
N industries				13

Significance levels : $*$: 10% $**$: 5% $***$: 1%

Table 68: Allen Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	-1.0e+02			
Unskilled	9.4572	-1.0658		
ICT	-98.6159	0.6428	1.3e+03	
NICT	6.9839	0.6530	-78.3287	2.3211

Table 69: Morishima Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	0.0000	33.6898	-2.0e+11	-5.8e+07
Unskilled	1.1e+04	0.0000	-2.0e+11	-5.8e+07
ICT	2.3e+03	3.4166	0.0000	-5.8e+07
NICT	1.1e+04	3.6387	-2.1e+11	0.0000

5.1.6 Italy

Table 70: Estimation results.

Skilled	-0.049***			
	(0.01)			
Unskilled	0.014	0.056***		
	(0.02)	(0.00)		
ICT	-0.039***	-0.085***	-0.111***	
	(0.00)	(0.00)	(0.00)	
NICT	0.074***	0.000*	0.000	0.122***
	(0.00)	(0.00)	(0.00)	(0.00)
Import	-0.000	0.000*	0.000	-0.000
	(0.00)	(0.00)	(0.00)	(0.00)
N obs				545
N industries				13

Significance levels : ∗ : 10% ∗∗ : 5% ∗ ∗ ∗ : 1%

Table 71: Allen Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	-7.7210			
Unskilled	1.1820	-0.9386		
ICT	-7.2570	4.5932	64.8609	
NICT	2.5471	0.4617	-10.2109	-0.9363

Table 72: Morishima Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	0.0000	6.4921	-1.4e+09	15.8581
Unskilled	201.0850	0.0000	-1.4e+09	4.1771
ICT	-5.9e+03	98.9530	0.0000	4.1771
NICT	224.2367	4.3787	-1.4e+09	0.0000

5.1.7 The Netherlands

Table 73: Estimation results.

Skilled	-0.062***			
	(0.01)			
Unskilled	0.043***	0.057***		
	(0.01)	(0.01)		
ICT	-0.036***	-0.020***	-0.026***	
	(0.00)	(0.00)	(0.00)	
NICT	0.055***	-0.080***	0.082***	-0.057***
	(0.00)	(0.01)	(0.00)	(0.01)
Import	0.000***	-0.000***	0.000***	-0.000*
	(0.00)	(0.00)	(0.00)	(0.00)
N obs				210
N industries				13

Significance levels : * : 10% ** : 5% * * * : 1%

Table 74: Allen Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	-9.7745			
Unskilled	1.6052	-0.6930		
ICT	-7.9802	-0.2489	-62.8595	
NICT	2.3599	0.4909	10.2362	-2.9703

Table 75: Morishima Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	0.0000	6.9415	-7.0e+08	-2.9e+05
Unskilled	188.8671	0.0000	-7.0e+08	-3.0e+05
ICT	1.5e+03	-0.1981	0.0000	-3.0e+05
NICT	178.2415	4.4467	-4.4e+08	0.0000

5.1.8 UK

Table 76: Estimation results.

Skilled	-0.049***			
	(0.01)			
Unskilled	0.014	0.019		
	(0.02)	(0.02)		
ICT	-0.039***	0.058***	0.129***	
	(0.00)	(0.00)	(0.00)	
NICT	0.074***	-0.091***	-0.149***	0.165***
	(0.00)	(0.00)	(0.00)	(0.00)
Import	-0.000	0.000	0.000*	-0.000**
	(0.00)	(0.00)	(0.00)	(0.00)
N obs				225
N industries				13

Significance levels : $*$: 10% $**$: 5% $***$: 1%

Table 77: Allen Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	-7.7322			
Unskilled	1.1799	-0.9248		
ICT	-7.1788	4.7164	100.2200	
NICT	2.5481	0.4288	-13.9472	-0.5144

Table 78: Morishima Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	0.0000	6.4158	-2.0e+09	12.8335
Unskilled	201.5124	0.0000	-2.0e+09	1.0023
ICT	-5.9e+03	102.0793	0.0000	1.0023
NICT	224.7185	4.2259	-2.0e+09	0.0000

5.1.9 US

Table 79: Estimation results.

Skilled	-0.049***			
	(0.01)			
Unskilled	0.014	0.019		
	(0.02)	(0.02)		
ICT	-0.039***	0.058***	0.129***	
	(0.00)	(0.00)	(0.00)	
NICT	0.074***	-0.091***	-0.149***	0.165***
	(0.00)	(0.00)	(0.00)	(0.00)
Import	-0.000	0.000	0.000*	-0.000**
	(0.00)	(0.00)	(0.00)	(0.00)
N obs				225
N industries				13

Significance levels : * : 10% ** : 5% *** : 1%

Table 80: Allen Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	-7.7322			
Unskilled	1.1799	-0.9248		
ICT	-7.1788	4.7164	100.2200	
NICT	2.5481	0.4288	-13.9472	-0.5144

Table 81: Morishima Elasticities

	Skilled	Unskilled	ICT	NICT
Skilled	0.0000	6.4158	-2.0e+09	12.8335
Unskilled	201.5124	0.0000	-2.0e+09	1.0023
ICT	-5.9e+03	102.0793	0.0000	1.0023
NICT	224.7185	4.2259	-2.0e+09	0.0000

5.2 Labor Market Regulation

To be added.

5.3 Product Market Regulation

To be added

6 Decomposition of the Relative Skilled premium

In this section we decompose the growth rate of the skill premium into a supply, a complementarity and a technological effect. Using the Shepard's lemma, we can write quantity q as

$$q = \frac{\partial (PQ)}{\partial p} = \frac{\partial P}{\partial p} Q + \frac{\partial Q}{\partial p} P = \frac{\partial P}{\partial p} \frac{P}{p} Q = v \frac{PQ}{p} \tag{31}$$

In this way, the skill premium is given by

$$\frac{p_s}{p_u} = \frac{v_s}{v_u} \frac{q_u}{q_s} \tag{32}$$

Taking the natural logarithms to p and differentiating with respect to time, the growth rates g are obtained:

$$g_p = g_v - g_q + g_{PQ} \tag{33}$$

, where

$$g_p = \left(\Lambda B_{pp} - I\right)^{-1} \left(g_q - \Lambda \beta_{pt} - g_{PQ}\right) \tag{34}$$

and

$$g_v = \frac{\partial \ln \left(\alpha_p + B_{pp} \ln p + \beta_{pt} t\right)}{\partial t} = \Lambda \left(B_{pp} g_p + \beta_{pt}\right) \tag{35}$$

where Λ is a diagonal matrix containing the shares; the vector of the growth rates of the input prices g_p can be rewritten as

$$g_p = \left(\Lambda B_{pp} - I\right)^{-1} \left(g_q - \Lambda \beta_{pt} - g_{PQ}\right) \tag{36}$$

and

$$g_{p_s} - g_{p_u} = \underbrace{\left(\phi_1 g_{qs} + \phi_2 g_{qu}\right)}_{SUPPLY} + \underbrace{\left(\phi_2 g_{qi} + \phi_4 g_{qn}\right)}_{COMPLEMENTARITY} + \underbrace{\left(\psi_1 \beta_{st} + \psi_2 \beta_{ut}\right) + \left(\psi_3 \beta_{it} + \psi_4 \beta_{nt}\right)}_{TECHNOLOGY} \tag{37}$$

Country	wage premium (%)	supply (%)	complementarity (%)	Technology (%)
AUT	3.60	-2.30	-2.50	8.40
DNK	0.35	-8.50	0.65	8.20
FIN	1.72	-0.34	-2.74	4.80
FRA	1.22	-8.99	0.41	9.80
GER	-0.20	-9.70	2.60	6.90
NLD	2.90	-6.00	1.70	7.20
UK	1.70	-1.00	0.20	2.50
USA	3.00	-5.00	1.00	7.00

Table 82: Decomposition of the Relative Skilled premium

7 Conclusion

To be added.

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