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The Trend in Labour Income Share: the Role of Technological Change and Imperfect Labour Markets

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Abstract

The non-constancy of factor shares is drawing the attention of many researchers. We document an average drop of the labour share of 8 percentage points for eight European countries and the US between 1980 and 2007. We investigate theoretically and empirically two mechanisms: the substitution between Information Communication Technology (ICT) and labour and the presence of hiring costs. We find that the ICT-labour replacement is a promising channel to explain the decline of the labour share, though labour market frictions takes part of its explanatory power over. In particular, hiring costs have a bigger role in Europe than in the US. Finally, by modelling the elasticity of substitution between ICT and labour as a function of institutional and structural variables, we find that it correlates with the share of routine occupations (positively) and with the share of high-skill workers (negatively).

1 Introduction

The labour income share (LS) is discussed in empirical studies dealing with income distribution as well as in several macroeconomic calibrations. Its constancy is one of the so called Kaldor's facts and a value of 2/3 is usually adopted. However, recent studies reveal that the LS is declining for most of the OECD countries since the 1980s [OECD (2012), Raurich et al. (2012), Arpaia et al. (2009)]. This evolution likely arises from recent tendencies of investment goods, as argued by Karabarbounis and Neiman (2014), or international trade competition as suggested by Elsby et al. (2013). It might be the case that this decline is only temporary; however, it shows up at the same time that the adoption of new technologies gives rise to job polarization and occupational displacement, phenomena that

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are considered, at least in the public debate, irreversible. Despite the extensive discussion on the latter, few studies so far addressed in a direct way the effect of technology on the labour market. We contribute to the literature by analysing theoretically and empirically the substitution between Information Communication Technologies (ICT henceforth) and labour, together with labour market imperfections as well as with institutional and structural labour market variables.

We firstly compute the labour share based on labour income data from the EU KLEMS database for eight European countries and the US. The aggregate LS dropped from 71 percent to 63 percent between 1980 to 2007[1]. There is a substantial heterogeneity of the speed and the timing of the decline, but, except for Denmark, all the countries display a persistent fall of the LS after 1990. Secondly, we look at the evolution of the price index for a specific type of capital input, namely for ICT. According to a wide range of studies, indeed, the decline of the price for computer and digital equipment is the source of important new tendencies in the production process, such as automation and occupational displacement. Provided by EU KLEMS is the gross fixed capital formation price index for ICT and non-ICT and we show that the decline of capital investment price is mainly connected to the downward evolution of ICT equipment price. Building on that, we set up a theoretical framework to give a rationale to the relationship between ICT price, hiring costs and the labour share. The model provides two harmful mechanisms for the labour share, a labour-ICT substitution effect and a hiring cost effect, that we quantify by estimating the elasticity of substitution between ICT capital and labour.

When we assess the model with the data, it turns out that under the assumption of perfect labour markets the elasticity of substitution between labour and ICT is 1.18, statistically different from one. It means that a decline of ICT price of 1 percent produces an increase of the stock of ICT over labour of 1.18 percent, generating a fall of the labour share. When we consider the model under labour market imperfections, the elasticity shrinks to 1.13, that means that the substitution effects loses some of its explanatory power in favour of the hiring cost effect. The more the elasticity approaches one, indeed, the lower is the substitution between ICT and labour. Interestingly, when we restrict our sample to Europe we find that the hiring costs have a stronger role, given an elasticity of 1.09.

The second aim of the paper is to assess to what extent the elasticity of substitution between ICT and labour is affected by country-specific labour market variables. The literature dealing with the impact of technological change on labour markets reveals that, on the one hand, the adoption of ICT raises the demand for high-skill workers (the skill-biased view) and, on the other hand, shrinks the employment share of routine occupations (the job polarization view). As regards the institutions, lower employment protection legislation and firm-level wage bargaining have been assessed as potential channels of the impact of higher international competition on the labour share (OECD, 2012). In this paper, we look as well at the role of unemployment benefit replacement rate and at union density. The main

[1] See O'Mahony and Timmer (2009) for an overview of the methodology and construction of the EU KLEMS database

result of our analysis is that countries with a high share of routine occupations (high-skill workers) reveal also a larger (smaller) elasticity of substitution between labour and ICT capital. In this sense, we illustrate in a direct way the job polarization phenomenon and the implications of ICT adoption for routine occupations and overall employment.

The paper proceeds as follows. Section 2 documents the decline of the labour share and of the capital price index, at aggregate and country level. Here we provide evidence of the different evolutions of the price of ICT and non-ICT capital. Section 3 discusses the latest contributions on the impact of technological change on the labour market. In particular, we review the job polarization theory and the role of ICT for routine tasks. This allows us in Section 6 to derive a theoretical setting that links the labour share, the ICT price and the hiring costs. Section 5 describes the data sources and the variables we use for the empirical analysis. In Section 6 we assess the validity of theoretical prediction and model the elasticity parameter as a function of country-specific labour market variables. The estimates reveal an elasticity between labour and ICT higher than one and a correlation between ICT-labour elasticity and the evolution of routine occupations. Lastly in Section 7 we adopt a time-varying coefficient analysis to the elasticity parameter.

2 The labour share and ICT facts

The shares of national income that go to labour and capital have been considered constant for many years. Kaldor (1955) writes that there has been a

> relative stability of these shares in the advanced capitalist economies over the last 100 years or so, despite the phenomenal changes in the techniques of production, in the accumulation of capital relative to labor and in real income per head. (pp. 83-84)

This fact has been well described with the use of a Cobb-Douglas production function, that implies a constant unitary elasticity of substitution between the production inputs and steady factor shares. However, in the last decades several studies highlighted a decline of the labour share for many developed countries. OECD (2012) reveals that the labour share dropped in average by 5 percentage point between early 1990s and late 2000s, arguing that the substitution between labour and the new technologies is probably the driving force of this decline and that increasing the employer-employee matching quality might help to reverse the trend. A similar drop is computed by Karabarbounis and Neiman (2014) who analyse 59 countries at industry level and claim that the decline of the price of investment goods has reduced the labour share, given an elasticity of substitution of about 1.25. Detailed research for the US comes from Elsby et al. (2013) who argue that the drop of the labour share is mainly experienced by the manufacturing sector, potentially due to the offshoring of labour-intensive production, and that changes in institutional setting are negligible.

Using the EU KLEMS dataset we compute the labour share as labour compensation over value added at current basic prices between 1970 and 2007. Due to data constraint, we focus

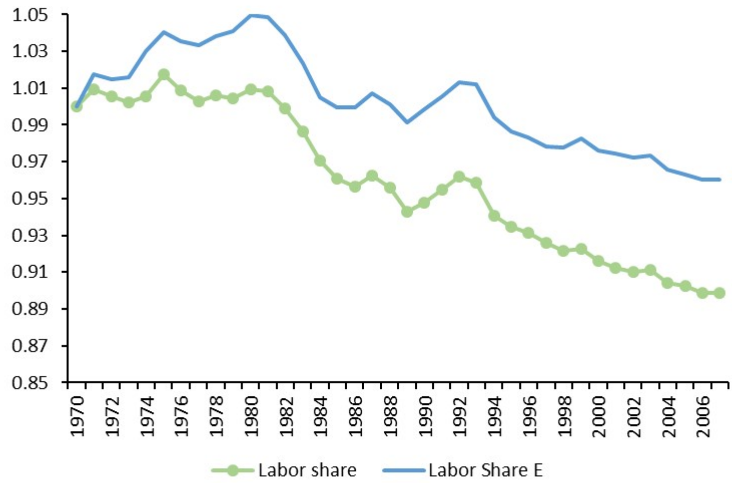

Figure 1: Aggregate labour share total labour force (blue line), aggregate labour share of employees (green line). Source: EU KLEMS.

on Austria, Denmark, France, Germany, Ireland, Italy, the Netherlands, Spain and the US[2]. We derive the labour share for two subsets of the labour force, namely the employees and the person engaged, that includes also the self-employed. Compensation of self-employed is imputed assuming that, at industry level, the compensation per hour of self-employed is equal to the compensation per hour of employees. This raises a number of issues, treated in details in O'Mahony and Timmer (2009), however for the purpose of our paper we rely only on employees. Figure 1 shows the year fixed effects for the two subsets. The blue line is the labour share using the compensation of employees and self-employed, while the green line uses only the compensation of employees. A clear drop in both series is visible starting from 1980, steeper for the LS with self-employed.

Concerning the possibility that the aggregate labour share shrunk due to changes in industrial composition, it is worth to mention that Karabarbounis and Neiman (2014), using EU KLEMS data, show that the within-industry component prevails.

The study of Karabarbounis and Neiman (2014) is the closest to ours as they assess the impact of capital price on the labour share. However we addressed our research on a specific capital asset, namely Information Communication Technology. The motivation is twofold: firstly, ICT equipment, unlike non-ICT, is revealing a substantial fall in its investment price; secondly, ICT is the main candidate to substitute labour into the production (we give further details on that in the next section). Figure 4 shows the price index for total, ICT and non-ICT assets. The measure is the one used in Karabarbounis and Neiman (2014), namely gross fixed capital formation price index divided by gross value added price index. Looking at the evolution of the time series, it is clear that the decline of the total assets price index is mainly related to the ICT equipment.

[2]From 1990, our EU sample represents more than 78 percent of the EU15 value added.

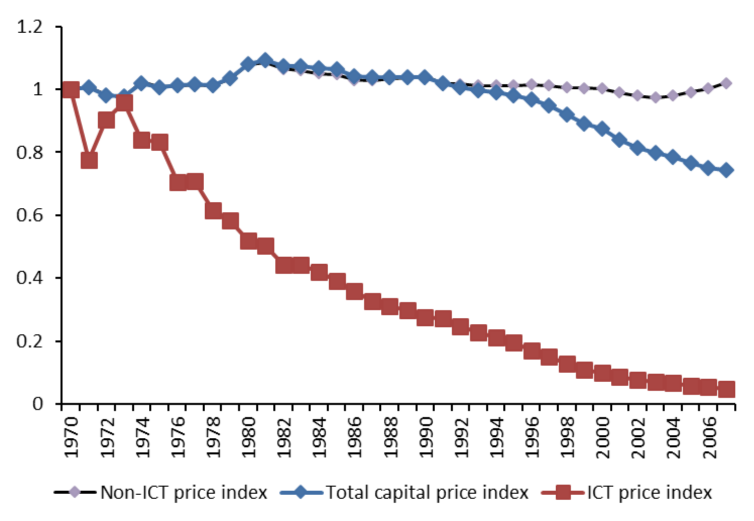

Figure 2: Price index per type of capital and total (average over the countries, 1970=1, source: EU KLEMS, own calculation)

Several studies on ICT equipment have been carried out after year 2000, when new data on new technologies became available and allowed to investigate their contribution to output and productivity. The stylized facts that emerged are the following: firstly, ICT-producing industries experienced a high productivity growth rate between 1979 and 2001; secondly, similar values for labour productivity in ICT producing sectors has been found between US and EU, as well as within Europe; finally, ICT-producing industries played a pivotal role in explaining the high labour productivity correlation among EU countries [3].

Connected with these facts, we observe a trend in the price for investment in ICT. We computed that by making use of the nominal and real gross fixed capital formation index given by EU KLEMS dataset. Table 1 shows the average price in ICT capital for three time spells between 1976 and 2005. In the period 1976-1985, almost all the countries experienced a substantial increase, with the exception of Denmark. In the late 1980s and early 1990s the decline of the ICT investment price begins for 6 European countries and the US and it becomes a clear common path from 1996 onwards. This evolution has been documented, among others, by Bosworth and Triplett (2000) and Jorgenson (2001) that explain the drop with the gain in capacity of microprocessors and storage devices. The acceleration post-1995 in Table 1 corresponds indeed to the marked decline in the price for semiconductors, employed in microprocessors for encoding information in binary form.

[3] O'Mahony and Van Ark (2003)

Table 1: Growth rate of ICT investment price (percent). Source: EU KLEMS.

Countries/Average	1976-1985	1986-1995	1996-2005
Austria	2.2	−3.3	−11.0
Denmark	−3.5	−9.2	−12.1
Spain	10.0	0.1	−4.7
France	9.5	−0.6	−0.9
Germany	0.5	0.0	−10.1
Ireland	8.8	−2.8	−10.9
Italy	11.1	−0.1	−8.4
Netherlands	2.5	−4.2	−9.1
US	3.4	−4.1	−8.7

3 ICT adoption and the labour market

The impressive speed of the adoption of ICT has raised several questions concerning its impact on the labour markets. Figure 3 visualizes the time series for ICT capital formation price index and the labour share of employees, that we use to estimate the elasticity. Despite a substantial heterogeneity, the labour share comoves in most countries with ICT price. The question is: how can the two trends be related to each other?

For a long time, the benchmark has been the capital-skill complementarity framework, developed, among others, by Krusell et al. (2000) according to which the technological change has been skill-biased and has pushed the demand for high-skill workers, resulting in an increase of the skill premium. Acemoglu (2002) further develops this view by arguing that the abundance of a production input (in that case high skill workers) can induce a biased technological change irrespective of the elasticity of substitution, with the latter playing a role mainly in determining the reward of the factor.

However, recent literature highlights that the high substitutability of capital with labour is likely biased against middle skill workers and a particular class of occupation. Autor et al. (2003), Autor et al. (2006) and Acemoglu and Autor (2011) claim indeed that in the US labour market a job polarization emerged around the 1990s, given a deterioration of the wage growth and employment opportunities of middle-skill workers and a substantial improvement for low and high skill occupations.

The theoretical argument builds on the concept of task. Following Acemoglu and Autor (2012), "a task is a unit of work activity that produces output. A skill is a worker's stock of capabilities for performing various tasks". Then workers perform tasks in exchange for wages. The intuition is that, if the assignment of skills to tasks is not one-to-one and if the set of tasks demanded in the economy is affected by technological change, we might end up with a non-monotone changes of the wage and of the employability on the skill (or wage)

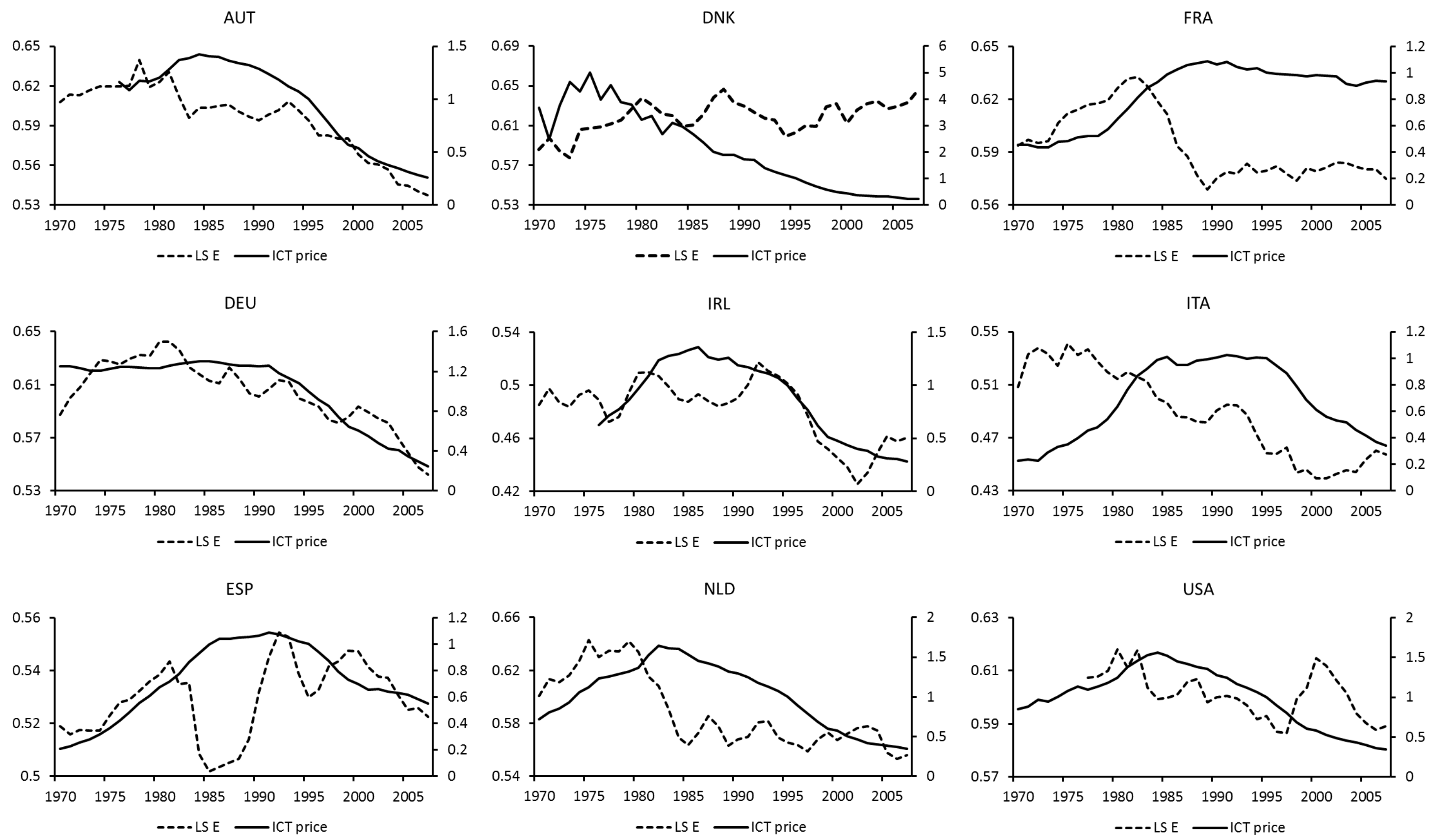

Figure 3: Employees labour share (green line, left axis), ICT index price (red line, right axis). Source: EU KLEMS

distribution. ICT capital has been more and more adopted for routine and "codifiable" tasks, previously carried out by middle skill workers, with a consequent drop of their wage growth and their employment. Consequently, depending on the employment share of routine occupations[4] and on how quickly workers react to the occupational displacement, we might expect that a higher adoption of ICT lowers the labour share.

Besides the US, there is a moderate consensus on the presence of job polarization also in Europe. Goos et al. (2014) focus on 16 Western European countries and show a pervasive job polarization between 1993 and 2010. Consoli and Roy (2015) find evidence of routine job displacement following ICT adoption for Germany, even though it seems that mainly high-rank occupations profit from this phenomenon.

In order to further investigate the phenomenon, we analyse the changes in occupational employment shares in Europe. We make use of a Eurostat dataset that relies on the International Standard Classification of Occupations and we focus on 9 major classes[5]. Figure 4 reports the percentage change of occupational employment shares for 4 time periods between 1993 and 2012 in the aggregate EU15[6]. From left to right are plotted the changes of managers, professionals and associate professionals (technicians belong also to this category), usually referred as abstract occupations; in the middle are four routine occupations, namely clerical, skilled agricultural, craft and plant workers; on the right-hand side of the figure are elementary occupations and service and sales workers, usually associated to manual tasks. The familiar U-shaped distribution is visible in all the periods and depicts the employment polarization in Europe.

4 The Model

The aim of this section is to develop a theoretical model that explains the evolution of the labour share depending on technological change and labour market imperfections. We set the model in steady state and we make use of two assumptions. Firstly, in contrast to those of ICT equipment, the productivity characteristics of workers are not observable before the match, therefore the hiring process of labour is affected by frictions, in terms of expenditures and time. Secondly, non-ICT capital has a constant elasticity of substitution with the remaining inputs, ICT capital and labour. We consider indeed that both ICT capital and labour are equipped with an equal stock of non-ICT capital, such as machines and plants. Employers produce output with a combination of labour force n, ICT capital k_I and non-ICT capital k_{NI} in a reduced form of production function of the type

[4]We report the employment share for abstract, routine and manual occupation in Table 4 in the appendix

[5]We neglect the armed forces as the cited studies above do.

[6]EU15 refers to Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, United Kingdom, Austria, Finland and Sweden. It is calculated by aggregating totals from the Member Sates

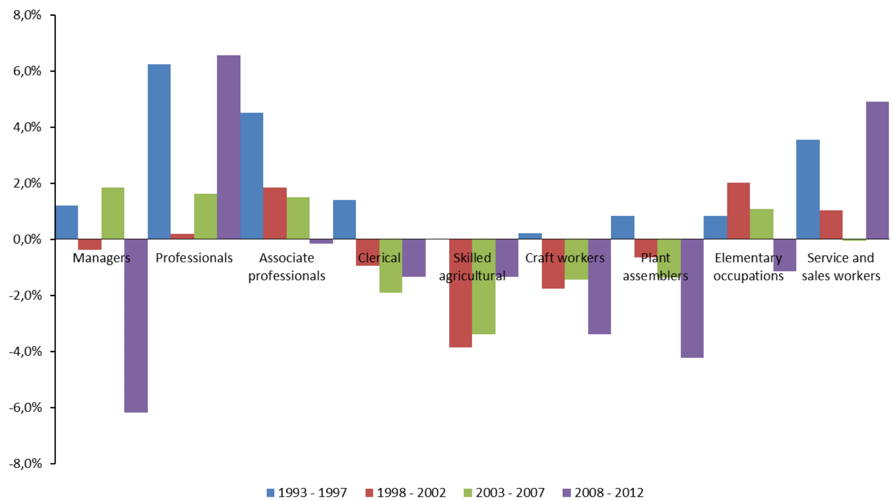

Figure 4: Changes in employment share per occupations. EU15 countries between 1993 and 2012 (percent, source: Eurostat)

$$y = \left\{ \beta R^{\frac{\varepsilon(\sigma-1)}{(\varepsilon-1)\sigma}} + (1-\beta) k_{NI}^{\frac{\sigma-1}{\sigma}} \right\}^{\frac{\sigma}{\sigma-1}},$$

$$R = \alpha k_I^{\frac{\varepsilon-1}{\varepsilon}} + (1-\alpha) n^{\frac{\varepsilon-1}{\varepsilon}},$$

where α and β are distribution parameters, ε is the elasticity of substitution between ICT capital and labour and σ is the elasticity between non-ICT capital and the aggregate input of ICT capital and labour. Moreover, we consider that labour markets are subject to frictions and that firms have to post vacancies as well as train the new employees. Thus, we assume that there is a real cost c that embeds the cost for posting the vacancy (search cost), the cost for training the new worker (adaptation cost) and the opportunity cost. According to the standard search and matching framework, the aggregate flow of workers into employment in each period is given by $vq(\theta)$, where v is the number of vacancies and $q(\theta)$ is the vacancy filling rate. Given an exogenous separation rate s, the outflow of worker from employment to unemployment is sn. This implies that the law of motion of employment follows

$$n_{t+1} = (1-s_t)n_t + v_t q(\theta_t), \tag{1}$$

from which we get the steady state relation between employment and vacancies

$$sn = vq(\theta). \tag{2}$$

Capital input is hired at the real cost p that represents the investment price. The law of motion for type j of capital is given by

$$k_{j,t+1} = k_{j,t} + i_{j,t+1} - \delta_{j,t} k_{j,t}, \tag{3}$$

where k_j is the stock of capital j, i_j is the flow of new capital and $\delta_{j,t}$ the depreciation rate. In steady state $k_{j,t+1} = k_{j,t}$, that implies trivially that capital formation must be equal to consumed capital

$$i_{j,t+1} = \delta_{j,t} k_{j,t} \tag{4}$$

Real profit is then maximised subject to the equilibrium condition for employment 2 and the one for capital formation 4 - see Appendix for details -

$$\pi = y - wn - cv - p_I i_I - p_{NI} i_{NI}, \tag{5}$$

where w is the real wage. From that, we compute the first-order conditions:

$$\begin{aligned}
\partial n :& y^{\frac{1}{\sigma}} \xi (1-\alpha) n^{-\frac{1}{\varepsilon}} = w + \lambda_n s, && (6)\\
\partial v :& \lambda_n = \frac{c}{q(\theta)}, && (7)\\
\partial k_I :& y^{\frac{1}{\sigma}} \xi \alpha k_I^{-\frac{1}{\varepsilon}} = -\lambda_I \delta_I, && (8)\\
\partial i_I :& \lambda_I = -p_I, && (9)\\
\partial k_{NI} :& y^{\frac{1}{\sigma}} (1-\beta)(k_{NI})^{\frac{1}{\sigma}} = -\lambda_{NI} \delta_{NI}, && (10)\\
\partial i_{NI} :& \lambda_{NI} = -p_{NI}, && (11)
\end{aligned}$$

where the λ_n, λ_I and λ_{NI} are the Lagrange multipliers with respect to employment and to the two types of capital and $\xi = \beta R^{\frac{\sigma-\varepsilon}{\sigma(\varepsilon-1)}}$. By substituting constraint (6) into (7), we get the labour demand

$$n = \frac{y^{\frac{\varepsilon}{\sigma}} \xi^{\varepsilon} (1-\alpha)^{\varepsilon}}{(w + c_v)^{\varepsilon}}, \tag{12}$$

where c_v represents the total hiring cost per employee[7]. Equation 12 tells us that labour demand is a derived demand and depends negatively on the wage, as the classical framework states. But interestingly, it gives also the intuition on how the labour input is affected by search frictions and the substitution with ICT capital. In a context of high substitutability between labour and ICT capital, namely with $\varepsilon > 1$, higher vacancy cost per employee or higher wages have a stronger negative impact on the amount of labour demanded because it is more convenient to run the same production with capital.

[7]We multiply and divide the term $cs/q(\theta)$, resulting from the substitution of equation 7 into 6, by n/v and we get $c\frac{sn}{q(\theta)v}\frac{v}{n}$. In steady state, the flows of workers into and out of unemployment, sn and $q(\theta)v$ respectively, are equal and we end up with the expression $c_v = \frac{cv}{n}$, namely the total cost of vacancies per employee.

Constraint (8) and (9) give the demand for ICT capital

$$k_I = \frac{y^{\frac{\varepsilon}{\sigma}} \xi^{\varepsilon} \alpha^{\varepsilon}}{P_I^{\varepsilon}}, \tag{13}$$

where $P_I = p_I \delta_I$, and we use 13 to substitute $y^{\frac{\varepsilon}{\sigma}} \xi^{\varepsilon}$ into n, that gives

$$n = \left(\frac{1-\alpha}{\alpha}\right)^{\varepsilon} \frac{P_I^{\varepsilon} k_I}{(w+c_v)^{\varepsilon}}. \tag{14}$$

To compute the labour share we multiply both sides of equation 14 by w/y,

$$LS = \frac{w}{y}\left(\frac{1-\alpha}{\alpha}\right)^{\varepsilon} \frac{P_I^{\varepsilon} k_I}{(w+c_v)^{\varepsilon}} \tag{15}$$

and finally we use constraints 10 and 11 to solve for y and substitute it into equation 15, obtaining the final expression for the labour income share

$$LS = Hw\left(\frac{P_I}{w+c_v}\right)^{\varepsilon} \frac{k}{P_{NI}^{\sigma}}, \tag{16}$$

where $k = \frac{k_I}{k_{NI}}$. The economic prediction of the model comes from the combination of the elasticity parameter ε, the costs and the quantities of the inputs. Given the flat evolution of the non-ICT relative price in Figure , we clarify the implications of two different ranges of values of ε, under a unitary elasticty σ:

- if $\varepsilon = \sigma = 1$, the two functions are of the type Cobb-Douglas. Interestingly, if we assume no hiring costs, we end up with a LS affected only by the investment price ratio and the stock ratio of ICT and non-ICT. Given an elasticity between ICT and non-ICT capital equal to one, deviations of both price and stock ratios cannot provoke a decline of the labour share. This implies that, in order to predict changes of the factor shares in a Cobb-Douglas setting, one should embed some degree of imperfection in the labour market[8];

- if $\varepsilon \neq 1, \sigma = 1$, labour and ICT may be employed as complements or substitutes into the production and changes in the ICT price have different impact on the labour share. To see that, we derive the change of the LS with respect to P_I:

$$\frac{\partial LS}{\partial P_I} = Hw\varepsilon \frac{P_I^{\varepsilon-1}}{(w+c_v)^{\varepsilon}} \frac{k}{P_{NI}}. \tag{17}$$

  If ε is lower than one, a decline of the ICT price increases the labour share, because the price change is higher than the stock change. Conversely if the elasticity is higher than one, the labour share declines because the ICT stock increases more than the downfall of the ICT price.

[8] It would be equivalent to assume frictions in the capital markets, that we exclude here.

5 Data

Our analysis uses country-level data from EU KLEMS on compensation and number of employees, stock, depreciation, investment and price index of ICT as well as of non-ICT capital. Most of the observations are available between 1970 and 2007, while for Germany we have two series, one from 1970 until 1991 and the other from 1991 to 2007, that we merged using the overlap in 1991. We focus on the labour share of employees and we compute that as compensation of employees over value added.

Concerning the total vacancy cost, we set

$$cv = c_m m + c_u u, \tag{18}$$

where m is the number of the matches, u is the number of unsuccessful vacancies and c_m, c_u the relative costs. For the matches we consider the number of workers flowing into employment from inactivity, unemployment and job-to-job transition per year[9]. This total flow into employment is available in the Eurostat database from 2010 to 2012 only. Therefore we use the ILO annual flow rates from unemployment to employment and the OECD unemployment level data to construct a time series of worker flows starting in 1984. However, this series does not comprise flows into employment from inactivity and job-to-job transition. As a consequence, we calculate an average scale factor α between the Eurostat and the ILO/OECD series using the time span in which they overlap (2010-2012). Assuming that α is constant over time, it can be applied to the ILO/OECD series in order to estimate the total worker flow into employment for the period before 2010[10].

Concerning the unsuccessful vacancies, according to the Data Warehouse of the German Federal Employment Agency, they amount to 46 percent of the matches[11].

As regards the cost of the matches c_m, we consider the search costs, the adaptation costs (initial training and lower productivity) and the opportunity costs. The best we can do is to assume the first two costs as a constant share of the wage. We make use of the result of Muehlemann and Pfeifer (2016) for Germany and of the German Federal Statistical Office and compute the vacancy and adaption costs together as 14 percent of the annual compensation per employee.

We define the opportunity cost as the foregone profit arising when the filled vacancy becomes productive later than expected by the employer. Using the wave 2014 of the German Job Vacancy Survey (JVS) of the Institute for Employment Research (IAB), we find that the timespan between the date the employer expects to fill the vacancy and the beginning of the employment relationship is in average 22 days. Therefore, we compute the opportunity cost as annual labour productivity minus annual wage, weighted by the

[9] We calibrate the job-to-job transitions as 40 percent of all the separations from employment, in line with Fallick and Fleischman (2004), Nagypál (2005) and Hobijn and Sahin (2007).

[10] The correlation between the unemployment level from ILO, OECD and the Eurostat dataset is larger than 0.99.

[11] The series goes back only to December 2000, therefore we focus on a range between 2000 and 2003

duration of the opportunity cost.

Concerning the cost of an unsuccessful vacancy c_u, we consider the vacancy costs and the opportunity costs only. We don't have information on the cost spent for an unsuccessful vacancy, but we can infer it from the duration of the vacancy. From the JVS we know that un unsuccessful vacancy lasts in average 140 days (against the 59 days of a successful vacancy). We combine this information with the result of Carbonero and Gartner (2017) on the correlation between search cost and search duration for Germany and we find that an unsuccessful vacancy costs 18 percent more than the one that turns into a match. Thus, we calibrate the vacancy cost as 6 percent of the annual compensation per employee. Finally, the opportunity cost amounts to the whole annual foregone profit.

We run a robustness check to allow for the possibility that an unsuccessful vacancy is followed by a new vacancy. According to the JVS in 2014, 79 percent of the unfilled vacancies become new vacancies. For them we assume that the employer is able to fill the position at the second round, thus the opportunity costs refer only to the period between the expected filling date in the first round and the starting date of the employment relationship in the second round. For the remaining 21 percent of the unfilled vacancies we count as opportunity cost the period between the expected filling and the rest of the year. All in all, the estimates from this calibration do not bring to different conclusions.

6 Estimation

The impact of ICT investment price on the labour share is closely related to the elasticity of substitution between labour and ICT-capital, as we have seen in Section . In order to assess this elasticity, we take the log of equation 16 and we provide two specifications, one without and one with hiring costs

$$lnLS_{it} = a_i + \varepsilon ln\frac{P_{I,it}}{w_{it}} - \sigma lnP_{NI,it} + lnw_{it}k_{it}, \tag{19}$$

$$lnLS_{it} = a_i + \varepsilon ln\frac{P_{I,it}}{w_{it} + c_{v,it}} - \sigma lnP_{NI,it} + lnw_{it}k_{it}, \tag{20}$$

These are the empirical equations we use to check the theoretical predictions. As it is implied by the theoretical model, in both equations the coefficient of the last term is one, thus the results will concern only the elasticity parameters ε and σ.

Table 2 reports the estimate with country fixed effects of the elasticity of substitution between labour and ICT (ε) and the elasticity between non-ICT capital and the other 2 inputs (σ). Columns 1 and 2 refer to equation 19, where we assume frictionless labour markets. The ICT-labor elasticity is 1.18 and significantly different from 1, that means that a decline of ICT price of 1 percent generates a increase of the ICT stock over labour of about 1.18 percent. Thus ICT price is a plausible channel to explain the evolution of the labour share and the CES function is a good candidate to model it. The estimated elasticity of non-ICT capital with the rest of the inputs instead is not statistically different from one, namely the compounded production function seems of the form Cobb-Douglas.

Table 2: Estimation of equations 19 and 20 with country FE. Dependent variable: logarithm of LS (robust standard error in parenthesis)

Specification	**1**	**2**	**3**	**4**
		Europe only		**Europe only**
ε	1.18	1.13	1.13	1.09
	(0.02)	(0.02)	(0.02)	(0.02)
σ	1.19	1.22	0.96	0.96
	(0.17)	(0.15)	(0.21)	(0.20)
Hiring costs	-	-	Yes	Yes
Obs	196	165	196	165
R^2	0.96	0.98	0.95	0.97

We turn now to the model that accounts for the hiring costs. With this exercise, we can assess the plausibility of the substitution effect depending on whether the elasticity parameter gets closer to or further from one. The results of the estimation of equation 20 are displayed in the last two columns. We estimate the elasticity by calibrating the term *cv* as it is explained in the previous section; in this case we end up with an elasticity of substitution between ICT and labour of about 1.13, lower than in the case without hiring costs but significantly different than one. This means that a decline of the labour share is still explained by the downfall of the ICT price but at a lower intensity. In other words, including hiring costs into the model seems to erode part of the explanatory power of the substitution effect.

To see that, we compute the labour share predicted by the evolution of the ICT price by plugging into equation (18) firstly the smallest (1.13) and then the largest (1.18) elasticity. Thus, the difference between the two series represents the loss of explanatory power of ICT price. We do the same for the hiring cost measure, by predicting the labour share with the average hiring cost per country as well as with annual data. The difference gives a size of the gain in the explanatory power of the hiring cost. Figure 5 displays the loss of and the gain in the explanatory power of ICT price and hiring costs respectively. While transitory fluctuations differ, the similar trending behaviour suggests that the portion of reduction of the labour share that is not provoked by the substitution effect is fairly well explained by the adjustment cost effect.

Lastly, we check for any structural differences between Europe and the US. In column 4 we estimate ε and σ only for the EU sample; interestingly, the elasticity moves further towards one. This implies that the costly process of hiring the labour input explains, more in Europe than in the United States, the decline of the labour share.

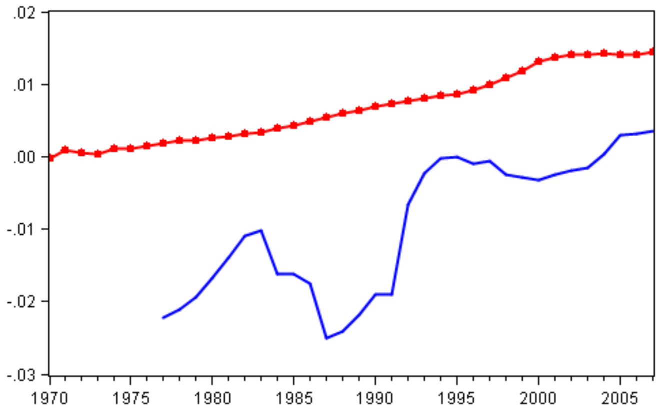

Figure 5: Gain in the predictive power of hiring costs (blue line) vs the loss of predictive power of ICT price (red line). Source: own calculation)

7 A time-varying analysis for the elasticity of substitution

The second part of the empirical analysis seeks to verify to what extent the impact of ICT on the LS varies with structural and institutional characteristics.

Among the institutional factors, we consider the role of a set of core labour market regulations: firing restrictions, wage bargaining level, union density and replacement rate. By limiting the reallocation of workers or by discouraging the reentry into employment, they might indeed affect the substitution between labour and capital and induce to a more capital-intensive production. Wage bargaining have unclear effects on the labour share, given that it influences mainly the wage dispersion, as shown in Dahl et al. (2013).

Concerning the composition of the labour force, we investigate whether the elasticity of substitution comoves with the share of high-skill workers and with the share of workers involved in routine tasks. Thus we are able to test in a panel framework the capital-skill and the job polarization hypotheses.

For this purpose, we adopt a panel-varying coefficient approach that allows for persistence and stochastic shocks. We use employment per occupation from EUROSTAT to compute the employment share of routine occupations of the European countries in our sample, while for the US we adopt employment from ILO. The share of high-skill workers is computed using the employment per skill group from EU KLEMS. Finally, concerning the labour market institutions, we use the employment protection legislation, the unemployment benefit replacement rate from OECD and the wage coordination as well as the union density from the ICTWSS[12].

[12]Database on Institutional Characteristics of Trade Unions, Wage Setting, State Intervention and Social Pacts from 1960 to 2010

7.1 The PVC Model

Binder and Offermanns (2007) have suggested a model for functional coefficient dependence in an error-correction cross-country panel data framework. In particular, their approach is parsimonious by employing the homogeneity argumentation within the pooled mean group (PMG) model of Pesaran et al. (1999): due to the different nature of mainly idiosyncratic short-run fluctuations versus the more structurally founded long-run equilibrium relationship, it appears straightforward to generalize the homogeneous long-run parameters to homogeneous functions of conditioning variables.

Although this approach entails a large degree of flexibility by employing orthogonal polynomials in the conditioning variable, it may not be suited for all models of state-dependent effects. In particular, the strict homogeneity assumption on the functional form across countries might not always be appropriate beyond the PMG framework. Here, we wish to generalize the functional coefficient dependence idea of Binder and Offermanns (2007) in three aspects: first, we allow for a country-specific fixed effect in the otherwise homogeneous functional form. Second, we introduce stochastic variation in the final effect through a state-space specification. This will enable the model to generate variation also across time, even if the candidate conditioning variable does not prove to have a significant impact on the final effect. Third, our modification to the state-space framework will allow us to take account of more than one conditioning variable, which was practically not feasible in the Binder and Offermanns (2007) approach, at least for desirable degrees of flexibility.

These aspects appear to be desirable features for a model of the elasticity of substitution between labor and ICT capital. The approach outlined above enables us to generalize the fixed-effect panel regression model with interaction terms to a model where the elasticity is specified as a latent variable which is determined by a panel state-space representation. This framework brings two main advantages. First, it solves the problem of the unit of measurement coming from a simple interaction between the covaring variables and the regressor of the elasticity: while the interaction approach is sensitive to linear transformations of the interaction variable, the state space approach is not. Second, it should be less subject to criticism concerning the right choice of the conditioning variable: if a candidate variable has no impact on the elasticity, the estimation is able to "reject" its influence in favour of an idiosyncratic stochastic time-varying elasticity. In case of the interaction approach, the estimation would have to reject it in favour of a constant homogeneous elasticity.

In the current section, the econometric framework for estimating the panel-varying coefficient (PVC) model is presented in generic notation. Our model is given as follows:

$$y_{it} = c_i + \theta_{it}(s_{it})' x^*_{it} + \gamma' \omega_{it} + u_{it}, \qquad u_{it} \sim N(0, \sigma^2) \tag{21}$$

where c_i is the (mean) fixed effect, $\theta_{it}(s_{it})$ represents the vector of PVCs of the corresponding set of k^* regressors x^*_{it} conditional on the vector s_{it}, and γ denotes the m-dimensional vector of coefficients of the set of regressors w_{it}. The r-dimensional vector s_{it} represents a set of exogenous indicators (the conditioning variables) that are supposed to drive the final effect of x^*_{it} on y_{it}, the vector θ_{it}.

In order to implement the model, we slightly change its notation and specify the following state space model:

$$y_{it} = z'_{it}x_{it} + \gamma'\omega_{it} + u_{it}, \qquad u_{it} \sim N(0,\sigma^2) \tag{22}$$

$$z_{it} = \delta_i + Az_{i,t-1} + Bs_{it} + v_{it}, \qquad v_{it} \sim N(0,Q) \tag{23}$$

where the vector $x_{it} = (1,\ x^{*\prime}_{it})'$ has dimension $k = k^* + 1$ and comprises the regressors x^*_{it} as well the constant, A is a $k \times k$ diagonal coefficient matrix, and $B = (0,\ \beta_2,\ \dots, \beta_k)'$ has dimension $k \times r$. The first element of the k-dimensional latent variable vector z_{it} is determined to capture the time-invariant fixed effect, and the remaining $k-1$ elements $z_{2,it}$ to $z_{k,it}$ represent the PVCs $\theta_{j,it}(s_{it})$, $j = 1,...,k^*$, of x^*_{it}. In particular, the restrictions to the parameter vector δ_i and to the parameter matrices A and B (as well as to the variance matrix Q) imply the following state equations:

$$z_{1,it} = 0 + 1 \cdot z_{1,i,t-1} + 0' \cdot s_{it} + 0 \tag{24}$$

$$z_{2,it} = \delta_{2,i} + \alpha_2 z_{2,i,t-1} + \beta'_2 s_{it} + v_{2,it}, \tag{25}$$

such that the fixed effect for country i, $z_{1,it} \equiv z_{1,i} = c_i$ is determined through its initial value $z_{1,i,0}$. The other PVCs $z_{j,it}$, $j = 2,...,k$, are determined through a country-specific constant, the homogeneous coefficient α_j on their own lag, the homogeneous effect β_j of all conditioning variables, s_{it}, and the stochastic component $v_{j,it}$.

The model is estimated by a maximum likelihood approach using the Kalman filter. Hence, we obtain a sequence of conditional expectations for z_{it} given information from the previous period, i.e. $z_{i,t|t-1}$. For better interpretation, we compute the so-called smoothed states defined as $z_{i,t|T}$, i.e., estimates of the states given end-of-sample information.

7.2 Setup

We hypothesize that the elasticity of substitution between labour and ICT capital is a function of employment protection legislation (EPL), the degree of wage coordination (COOR), the union density (DENS), the replacement rate (REPL) the share of high-skill workers (HSKILL) and the share of routine occupations (ROUT) in the economy.

We set our baseline specification (equations 24 and 25) as follows: for the dependent variable, we have

$$y_{it} = \ln LS_{it} - \ln w_{it} - \ln k_{it},$$

as the regressors we have

$$x_{it} = (1, \quad \ln P_{I,it} - \ln w_{it}),$$

$$\omega_{it} = -\ln P_{NI,it}$$

and as the conditioning variables we have

$$s_{it} = (EPL_{it}, COOR_{it}, DENS_{it}, REPL_{it}, HSKILL_{it}, ROUT_{it}).$$

Given the apparent non-stationarity of both, the dependent variable and the regressors, as well as the short time span of our sample, we estimate the model in first differences of y_{it}, x_{it}, and ω_{it}. By restricting the coefficient on the state variableâĂŹs own lag, α_2, to one, we allow for permanent deviations of the elasticity from any previous level. As this model choice implies a random walk-type evolution of the elasticity over time, we have to eliminate potentially distortionary drift effects from the other terms in the state equation by setting the intercept $\delta_{2,i}$ to zero and demeaning the conditioning variables. Note that these modifications do not eliminate the cross-section variation in the conditional means of the elasticity, as the initial value of the state variable is allowed to differ across countries and serves as an intercept. Lastly, due to data constraint we leave Ireland out.

7.3 Results

Table 3 shows the estimation results for the state equation. Given the high insignificance of the coefficient, in column 2 we exclude *COOR* from the regression. The most significant influences on the PVC of the adjusted ICT price are exhibited by the share of high-skill workers (negative) and the share of workers in routine occupations (positive). Interestingly, the impact of these variables on the elasticity of substitution is almost identical in opposite directions. Among the institutional variables, employment protection legislation and union density reveal a weak negative correlation. This is line with the view that these institutions protect the labour force from layoffs in the course of reallocation. The replacement rate displays instead a positive correlation with the elasticity of substitution. This result would be expected in case a higher replacement rate leads to a longer unemployment duration[13].

In sum, the PVC estimates suggest two main points. Firstly, that countries with a high share of routine occupations reveal also a high elasticity of substitution between labour and ICT capital. This is consistent with the job polarization view and with the idea that the replacement effect between labour and ICT affects mainly those occupations involved in repetitive tasks. Moreover, given the connection of the elasticity of substitution and the labour share, the results imply that the decline of the labour share might have been more marked for those countries that have a larger share of workers in routine occupations. Secondly, that new technologies are complementary with skilled labour, in line with the skill biased technological change view. As above, the insight from Table 3 is that countries with a high share of skilled workers might display a smoother decline or even an increase of the labour share. All in all, institutions seem to have a certain, albeit partly measured, effect, as it has been found by Elsby et al. (2013) and OECD (2012).

[13]See Bover et al. (2002) and Layard et al. (2005) on the relationship between unemployment benefit and unemployment duration.

Table 3: Effects of the conditioning variables on the elasticity of substitution between ICT and labour. 8 Countries, time period 1995 - 2005. *Impact* is computed as coefficient times standard deviation of the variable.

Determinants of the coefficient of $D(\ln P_{I,it}/w_{it})$		
HSKILL	-1.389	-1.378
p-value	0.173	0.077
impact	–0.096	–0.095
ROUT	1.382	1.389
p-value	0.117	0.113
impact	–0.093	0.094
EPL	-0.067	-0.067
p-value	0.289	0.216
impact	–0.054	–0.055
REPL	0.614	0.615
p-value	0.198	0.198
impact	0.085	0.086
DENS	-0.238	-0.237
p-value	0.291	0.281
impact	–0.046	–0.046
COOR	-0.001	-
p-value	0.987	-
impact	–0.001	-

8 Conclusion

The decline of the labour share, and the consequent increase of the capital share, is becoming increasingly prominent in economic research. This is due to its implications on income distribution as well as on the role of the labour input in the future. We provide an explanation for this trend connected with the most recent facts concerning technological progress and the labour markets. We consider the evolution of the ICT investment price together with job polarization and search frictions. Theoretically we predict a decline of the LS through two mechanisms: an ICT-labour substitution effect and a hiring cost effect. We test the plausibility of the two mechanisms by estimating the elasticity of substitution between ICT and labour. Under the hypothesis of perfect labour markets, we find an elasticity 1.18, implying that a decline of one percent of ICT price is associated to a increase of ICT capital stock over labour of 1.18 percent, generating a decline of the labour share. If we include hiring costs per employee into our model, the elasticity shrinks to 1.13. We show that part of the explanatory power of the substitution effect is lost in favour of the hiring cost effect.

In a second step, we analyse the determinants of the ICT-labour elasticity. For this purpose, we model the latter as a function of country-specific institutional and structural labour market variables, by applying an extension of Binder and Offermanns (2007) that allows for stochastic shocks through a state-space specification. We find that the employment share of routine occupations (high-skill workers) is positively (negatively) associated with the elasticity of substitution between labour and ICT. While institutions display a weaker role, we find that employment protection legislation and union density tend to decrease and the replacement rate tends to increase the substitution elasticity

Our result connects in a direct way the job polarization and the skill biased technological change to the macroeconomic trend of the labour income share. By the same token, Hutter and Weber (2017) find in a study for Germany that increasing wage inequality just as skill-biased technical change reduces overall employment. In general, this connection between the structure and the level of employment provides interesting opportunities for future research.

9 Appendix

We derive the first order conditions from:

$$\begin{aligned}\mathscr{L} = &\left\{\beta\left[\alpha k_I^{\frac{\varepsilon-1}{\varepsilon}}+(1-\alpha)n^{\frac{\varepsilon-1}{\varepsilon}}\right]^{\frac{\varepsilon(\sigma-1)}{(\varepsilon-1)\sigma}}+(1-\beta)k_{NI}^{\frac{\sigma-1}{\sigma}}\right\}^{\frac{\sigma}{\sigma-1}}-wn-cv\\&-p_Ii_I-p_{NI}i_{NI}+\lambda_n[vq(\theta)-ns]\\&+\lambda_I[\delta_Ik_I-i_I]+\lambda_{NI}[\delta_{NI}k_{NI}-i_{NI}]\end{aligned}$$

$$\begin{aligned}\partial n:&\left(\frac{\sigma}{\sigma-1}\right)y^{\frac{1}{\sigma}}\frac{\varepsilon(\sigma-1)}{(\varepsilon-1)\sigma}\beta(k_In)^{\frac{\sigma-\varepsilon}{\sigma(\varepsilon-1)}}(1-\alpha)\frac{\varepsilon-1}{\varepsilon}n^{-\frac{1}{\varepsilon}}-w-\lambda_ns=0\\&y^{\frac{1}{\sigma}}\beta(k_In)^{\frac{\sigma-\varepsilon}{\sigma(\varepsilon-1)}}(1-\alpha)n^{-\frac{1}{\varepsilon}}=w+\lambda_ns\\\partial v:&-c+\lambda_nq(\theta)=0\\&\lambda_n=\frac{c}{q(\theta)}\end{aligned}$$

By substituting λ_n we obtain

$$\begin{aligned}y^{\frac{1}{\sigma}}\beta(k_In)^{\frac{\sigma-\varepsilon}{\sigma(\varepsilon-1)}}(1-\alpha)n^{-\frac{1}{\varepsilon}}&=w+\frac{cs}{q(\theta)}\\n^{\frac{1}{\varepsilon}}&=\frac{y^{\frac{1}{\sigma}}\beta(k_In)^{\frac{\sigma-\varepsilon}{\sigma(\varepsilon-1)}}(1-\alpha)}{w+\frac{cs}{q(\theta)}}\\n&=\frac{y^{\frac{\varepsilon}{\sigma}}\beta^{\varepsilon}(k_In)^{\frac{\sigma-\varepsilon}{\sigma(\varepsilon-1)}\varepsilon}(1-\alpha)^{\varepsilon}}{(w+\frac{cs}{q(\theta)})^{\varepsilon}}\end{aligned}$$

Now, with respect to ICT capital

$$\begin{aligned}\partial k_I:&y^{\frac{1}{\sigma}}\beta(k_In)^{\frac{\sigma-\varepsilon}{\sigma(\varepsilon-1)}}(\alpha)k_I^{-\frac{1}{\varepsilon}}=-\lambda_I\delta_I\\\partial i_I:&-p_I-\lambda_I=0\\&\lambda_I=-p_I\end{aligned}$$

By substituting λ_I we obtain

$$k_I = \frac{y^{\frac{\varepsilon}{\sigma}} \beta^{\varepsilon} (k_I n)^{\frac{\sigma-\varepsilon}{\sigma(\varepsilon-1)}\varepsilon} \alpha^{\varepsilon}}{(p_I \delta_I)^{\varepsilon}}$$

We use the first order condition for capital ICT to substitute $y^{\frac{\varepsilon}{\sigma}} \beta^{\varepsilon} (k_I n)^{\frac{\sigma-\varepsilon}{\sigma(\varepsilon-1)}\varepsilon}$ into n

$$n = \left(\frac{1-\alpha}{\alpha}\right)^{\varepsilon} \frac{(p_I \delta_I)^{\varepsilon} k_I}{\left(\frac{cs}{q(\theta)} + w\right)^{\varepsilon}}$$

By using the FOC with respect to non-ICT capital and by multiplying the last expression by w/y, the labour share ends up having the following expression:

$$LS = (1-\beta)^{\sigma} \left(\frac{1-\alpha}{\alpha}\right)^{\varepsilon} \frac{(p_I \delta_I)^{\varepsilon}}{\left(\frac{cs}{q(\theta)} + w\right)^{\varepsilon}} \frac{k_I}{k_{NI}} \frac{1}{(p_{NI} \delta_{NI})^{\sigma}}$$

Table 4: Employment share of occupations per task group, percent average between 1993 and 2000

Countries/Average	Abstract	Routine	Manual
Austria	31	46	22
Denmark	37	35	28
Spain	26	45	29
France	35	43	22
Germany	37	42	22
Ireland	32	42	26
Italy	27	47	26
Netherlands	45	31	24
EU	34	40	24

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