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

Francesco Carbonero[*], Christian Offermanns [†], Enzo Weber[‡]

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Abstract

The non-constancy of factor shares is drawing the attention of many researchers. We contribute to the literature by documenting 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: a substitution effect between ICT and labour and an employment adjustment cost effect. We find that the ICT-labour replacement effect is a promising channel to explain the decline of the labour share, though it is partly dampened when we consider the hiring costs. In Europe, in particular, the latter seems to be the prevailing mechanism. Finally, by modelling the elasticity of substitution between ICT and labour as a function of labour market institutions and worker groups, we find that it is strongly positively correlated with the share of routine occupations. We interpret that as an unconventional way to illustrate the job polarization phenomenon.

1 Introduction

The labour income share (LS) is discussed in the 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 1980's [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 nontrivial phenomena in the labour markets, namely a

[*]Institute for Employment Research (IAB)
[†]Deutsche Bundesbank
[‡]Institute for Employment Research (IAB), University of Regensburg, IOS Regensburg

job polarization and an occupational displacement. Despite the extensive discussion on the latter, few studies addressed the effect of technology in a straight way. 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 compositional variables.

We firstly compute the labour share based on labour income data from the EUKLEMS database for eight European countries and the US. The aggregate LS dropped from 71% to 63% between 1980 to 2007. Concerning the industry heterogeneity, there is ambiguous evidence on whether this phenomenon takes place within or between industries. However, present data provide evidence of a stronger within-industry component. From EUKLEMS we collect data on investment price of ICT and non-ICT capital and we show that the decline of capital investment price is mainly connected to the 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 labour adjustment cost effect, that we quantify by estimating the elasticity of substitution between ICT capital and labour.

When we check the model with the data, it turns out that under perfect labour markets the elasticity of substitution between labour and ICT is about 1.18, meaning that the downfall of ICT price affects negatively the labour share. When we consider the model under labour market imperfections, the elasticity shrinks to 1.13, implying that the substitution effects loses some of its explanatory power in favour of the adjustment cost effect. Interestingly, when we restrict our sample to Europe we find that the adjustment cost effect has even 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 contributions in the literature concerning the impact of technological change on labour markets reveal, on the one hand, that the adoption of ICT raises the demand for high-skill workers (the skill-biased view) and shrinks the employment share of routine occupations (the job polarization view). Furthermore, lower employment protection legislation and firm-level wage bargaining have been analyzed as potential mechanisms of the impact of higher international competition on the labour share (OECD, 2012). The main 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. This is an unconventional way to illustrate the job polarization phenomenon.

The rest of 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 ICT and non-ICT capital. Section 3 discusses the most recent facts concerning 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 4 to derive a theoretical setting that links the labour share, the ICT price index and the hiring costs. Section 5 describes the data sources and the variables we use for the empirical analysis. Lastly, 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.

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.

This fact has been well described with the use of a Cobb-Douglas form of production function, that implies a constant unitary elasticity of substitution between labour and capital. 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 matching quality could 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 main drop of the labour share is experienced by the manufacturing sector, potentially due to the offshoring of labour-intensive production, and that changes in institutional setting are negligible.

Using the EUKLEMS 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 on Austria, Denmark, France, Germany, Ireland, Italy, the Netherlands, Spain and the US[1]. Figure 1 shows the year fixed effects of a panel regression for two measures of the LS. 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 the series is visible starting from 1980, steeper for the LS with self-employed. There are of course differences among countries, both in the timing as well as in the intensity of the decline, as we show later in a comparison with the ICT price index.

Looking at the sectoral differences, in the literature there is ambiguous evidence concerning the within or between-industries component of the LS decline. It is worth to mention,

[1] From 1990, the EU sample represents more than 78% of the EU15 value added.

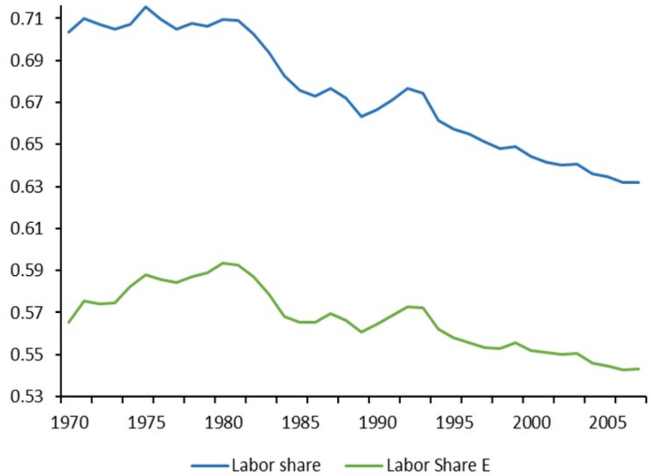

Figure 1: Aggregate labour share total labour force (blue line), aggregate labour share of employees (green line), computed as year fixed effects of a country and time fixed effects panel regression (source: EUKLEMS)

however, that Karabarbounis and Neiman (2014), using EUKLEMS, show that the within component prevails.

The study of Karabarbounis and Neiman (2014) is the closest to ours as they assess the impact of capital price index 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 2 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.

As far as the research on ICT assets is concerned, several studies 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: first, 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 [2].

Connected with these facts, we observe a trend in the price for investment in ICT. We

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

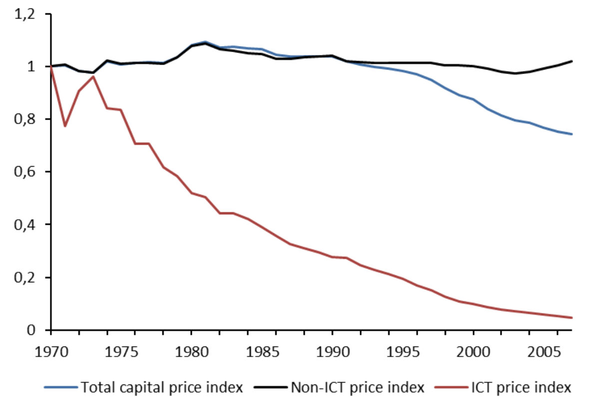

Figure 2: Price index per type of capital and total (average over the countries, 1970=1, source: EUKLEMS, own calculation)

Table 1: Growth rate of ICT investment price (percent)

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

computed that by making use of the nominal and real gross fixed capital formation index given by EUKLEMS dataset. Table 1 shows the average investment 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.

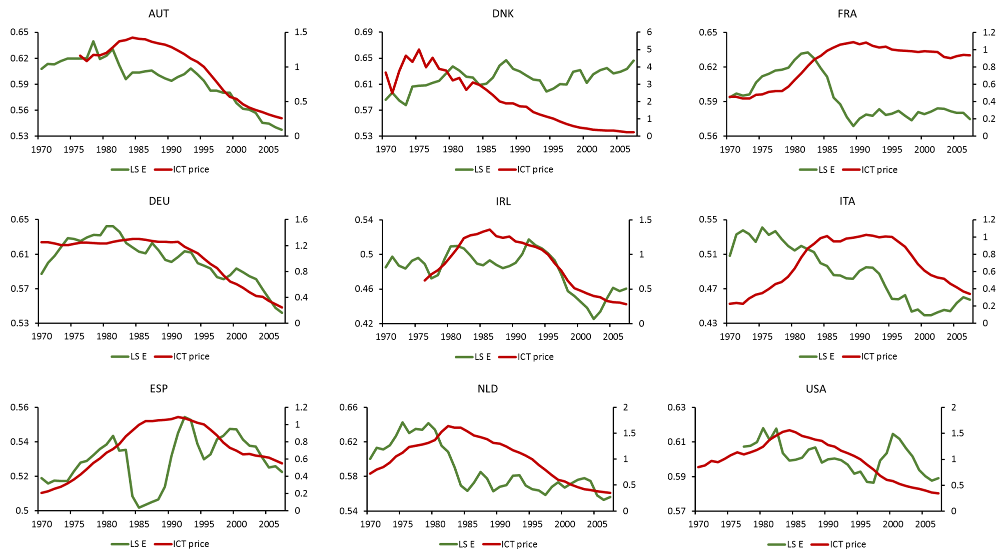

Figure 3: Employees labour share (green line, left axis), ICT index price (red line, right axis). Source: EUKLEMS

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 the presence of heterogeneity among countries, in many of them there is an interesting comovement of the evolution of the labour share and the one of 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, the recent literature dealing with the spillover effects of technology 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.

What we know from the job polarization theory is that there are routine tasks in the labour market that are negatively affected by technological developments. To be precise, 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 main intuition is that, if the assignment of skills to tasks is not one-to-one and if it is affected by technological change, we might end up with an improvement or a deterioration of the wage and the employment at the occupational level. Accordingly, 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 opportunities. Consequently, depending on the employment share of routine occupations[3] and on how quickly workers react to occupational displacement, we might expect an effect on 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[4]. Figure 4 reports the percentage change of occupational employment shares for 4 time spells between 1993 and 2012 in the aggregate EU15[5]. From left to right are plotted the employment shares of managers, professionals and associate professionals (technicians belong also to this category), usually referred as abstract occupations; then, we find four routine occupations corresponding to 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 spells and confirm the employment polarization in Europe.

4 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, the characteristics of capital equipment are clearly discernible compared to those of workers, therefore only the hiring process of labour is affected by frictions, in terms of expenditures and time.

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

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

[5] 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

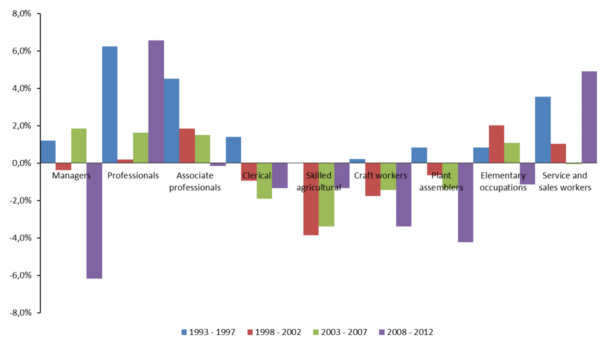

Figure 4: Changes in employment share per occupations. EU15 countries between 1993 and 2012 (percent, source: Eurostat)

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, like machines and plants, such that changes in non-ICT price do not lead to changes in the amount of ICT capital or labour. Output is obtained with the 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

$$Y = \left\{ \beta \left[\alpha K_I^{\frac{\varepsilon-1}{\varepsilon}} + (1-\alpha) N^{\frac{\varepsilon-1}{\varepsilon}} \right]^{\frac{\varepsilon(\sigma-1)}{(\varepsilon-1)\sigma}} + (1-\beta) K_{NI}^{\frac{\sigma-1}{\sigma}} \right\}^{\frac{\sigma}{\sigma-1}}, \tag{1}$$

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 job creation subject to a real cost c that embeds three types of cost: 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 inflow probability. Given an exogenous separation rate s, the outflow of worker from employment to unemployment is $s \cdot N$. This implies that the law of motion of employment follows

$$N_{t+1} = (1-s_t)N_t + V_t q(\theta_t), \tag{2}$$

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

$$sN = Vq(\theta). \tag{3}$$

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

$$K_{j,t+1} = K_{j,t} + I_{j,t+1} - \delta_{j,t} K_{j,t}, \tag{4}$$

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.

Real profit is then maximised subject to the equilibrium employment in (3) and the equilibrium condition for capital formation implied by (4) - see Appendix for details -

$$\Pi = Y - wN - cV - p_I - p_{NI}, \tag{5}$$

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

$$\partial N : Y^{\frac{1}{\sigma}} \xi (1-\alpha) N^{-\frac{1}{\varepsilon}} = w + \lambda_1 s, \tag{6}$$

$$\partial V : \lambda_1 = \frac{c}{q(\theta)}, \tag{7}$$

$$\partial K_I : Y^{\frac{1}{\sigma}} \xi \alpha K_I^{-\frac{1}{\varepsilon}} = -\lambda_2 \delta_I, \tag{8}$$

$$\partial I_I : \lambda_2 = -p_I, \tag{9}$$

$$\partial K_{NI} : Y^{\frac{1}{\sigma}} (1-\beta)(K_{NI})^{\frac{1}{\sigma}} = -\lambda_2 \delta_{NI}, \tag{10}$$

$$\partial I_{NI} : \lambda_3 = -p_{NI}, \tag{11}$$

where the λ_s are the Lagrange multipliers and $\xi = \beta(K_I L)^{\frac{\sigma-\varepsilon}{\sigma(\varepsilon-1)}}$. By substituting contraint (6) into (7), we get the labour demand[6]

$$N = \frac{Y^{\frac{\varepsilon}{\sigma}} \xi^{\varepsilon} (1-\alpha)^{\varepsilon}}{(w + \frac{cV}{N})^{\varepsilon}}. \tag{12}$$

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.
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

$$N = \left(\frac{1-\alpha}{\alpha}\right)^{\varepsilon} \frac{P_I^{\varepsilon} K_I}{\left(w + \frac{cV}{N}\right)^{\varepsilon}}. \tag{14}$$

[6] We multiply and divide the term $cs/q(\theta)$, resulting from the substitution of λ_1, 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 $\frac{cV}{N}$, namely the total cost of vacancies per employee.

In order to compute the labour share we multiply both sides of equation (14) by w/Y,

$$LS = \frac{w}{Y}\left(\frac{1-\alpha}{\alpha}\right)^{\varepsilon} \frac{P_I^{\varepsilon} K_I}{\left(w+\frac{cV}{N}\right)^{\varepsilon}} \tag{15}$$

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

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

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 2, we clarify the implications of two different categories 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 variations of the factor shares in a Cobb-Douglas setting, one should likely embed some degree of imperfection in the labour market[7];
- 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:

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

  In case ε is lower than one, a decline of the ICT price provokes an increase of the labour share, because the price change is higher than the stock change. Conversely if the elasticity is higher than one, it generates a reduction of the labour share because the ICT stock increases more than the downfall of the ICT price.

5 Data

Our analysis uses country-level data from EUKLEMS 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

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

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[8]. 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[9].

Concerning the unsuccessful vacancies, according to the Data Warehouse of the German Federal Employment Agency, they amount to 46% of the matches[10].

As regards the cost of the matches c_M, we consider the vacancy 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% of the annual compensation per employee.

We define the opportunity cost as the foregone profit arising when the filled vacancy becomes productive later in time 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 in which 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 duration of the opportunity cost.

Concerning the cost of an unsuccessful vacancy c_U, we consider the vacancy costs and the opportunity costs only. 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 (2016) on the correlation between search cost and search duration for Germany and we find that an unsuccessful vacancy costs 13% more

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

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

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

than the one that turns into a match. For this reason, we calibrate the vacancy cost as 6% of the annual compensation per employee. Finally, the opportunity cost amounts to the whole annual foregone profit.

We run two robustness checks to assess to what extent the results are driven by our calibration. Firstly, we allow for the possibility that an unsuccessful vacancy is followed by a new vacancy. According to the JVS in 2014, 79% 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% 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. Secondly, we calibrate the vacancy costs according the values computed in Carbonero and Gartner (2016) and the adaptation cost from Carbonero and Gartner (2016). Also in this case, the results do not differ substantially from the tables in section 6.

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 4. In order to assess this elasticity, we take the log of equation (9) and we provide two specifications, one without and one with hiring costs

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

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

where $C = w + \frac{cV}{N}$. These are the empirical equations we use to check the theoretical predictions. We estimate them with country fixed effects and cross-section weights. 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 parameter ε.

Table 2 reports the estimate 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 (18), where we assume frictionless labour markets. The ICT-labor elasticity is 1.18 and significantly different from 1. As it results from the theory, an elasticity higher than one associated to a fall of ICT price provokes a decline of the labour share. This means that the ICT price is a plausible channel to explain the evolution of the labour share and that the CES function is a 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 10 and 11 with country FE and robust SE. Dependent variable: logarithm of LS (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)
Frictions	-	-	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 the direction the elasticity parameter, because unity is the threshold that gives the mechanism underlying the decline of the labour share. The results of the estimation of equation (19) are displayed in the last 2 columns. In column 3 we estimate the elasticity by calibrating the term C 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 higher 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 (16) firstly the smallest (1.13) and then the largest (1.18) elasticity. The difference between the two series is 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. The two lines are rather parallel, suggesting 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, in the attempt of finding any structural difference between Europe and the US, in column 4 we estimate ε 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, in Europe more than in the US, the decline of the labour share.

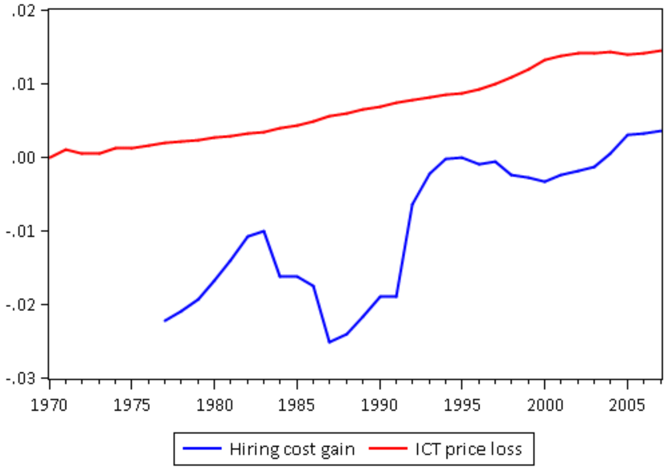

Figure 5: Gain in the predictive power of hiring costs (blue line) vs the loss of predictive power of ICT price (red line) (own calculation)

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: firing restrictions, wage bargaining level, union density and replacement rate. They all might affect the substitution between labour and capital and induce to a more capital-intensive production, either by limiting the reallocation of workers or restricting the ability of firms to react to international competition. Wage bargaining might have also a direct effect on the labour share, given that firm-level agreement are associated with high wage dispersion, as proved 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 EUKLEMS. Finally, concerning the labour market institutions, we use the employment protection legislation index and the replacement rate from OECD and the wage coordination index as well as the union density from the

ICTWSS[11].

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:

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

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

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 $x_{it} = (1,\ x^{*'}_{it})'$ 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 $B = (0,\ \beta_2,\ \ldots,\beta_k)'$ 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 $\theta_{j,it}(s_{it})$, $j = 1, \ldots, k^*$, 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:

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

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

$$\vdots$$

$$z_{k,it} = \delta_{k,i} + \alpha_k z_{k,i,t-1} + \beta'_k s_{it} + v_{k,it} \tag{26}$$

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 $z_{j,it}$, $j = 2, \ldots, k$, 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 (coord), the union density (dens), the replacement rate (repl) the share of high-skill workers (highskill) and the share of routine occupations (routine) in the economy.

We rewrite equation 12 and set our baseline specification as follows: for the dependent variable, we have

$$y_{it} = \ln(LS_{it}) - \ln(w_{it}) + \ln(K_{it}^{NICT}) - \ln(K_{it}^{ICT}),$$

as the regressors we have

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

,

$$\omega_{it} = (-\ln(P_{it}^{NICT}))$$

and as the conditioning variables we have

$$s_{it} = (EPL_{it},\ COOR_{it},\ DENS_{it},\ REPL_{it},\ HSSHARE2_{it},\ ROUT_{it}).$$

7.3 Main results

We estimate Equation (24) and (25) with both, the dependent variable and the PVC regressor, in first differences. Table 3 shows the estimation results for the state equation.

Table 3: Determinants of the coefficient of D(LOG(PICT/W))

	Coefficient	Standard error
epl	-0.047	0.030
coord	-0.003	0.021
dens	-0.016	0.092
repl	0.090	0.121
routine	0.361	0.132
highskill	-0.771	0.202
Dynamics	1.0000	Nan
Error variance	0.0010	0.0144

9 Countries, time period 1995 - 2005

The table reveals that statistically significant influences on the PVC of the adjusted ICT price are exhibited from *highskill* (negative) and *routine* (positive). Concerning the two institutional variables, only *epl* reveals some significant correlation with the elasticity of substitution.

As a remark, note that all results have been obtained under the restriction of setting the coefficient of the lagged state variable (entry "dynamics" in the tables) to one (random walk-type specification) and that the results are partly robust to relaxing this restriction.

In sum, the results deliver strong evidence that the share of high-skill workers and routine occupations have an important impact on the elasticity of the labor share with respect to the price of ICT. Even though the estimates are not directly comparable to the elasticities estimated under the level formulation that is derived from the theoretical model and used in related literature, PVC approach - the latter in a more flexible framework - 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 reveal also 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. 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.

8 Conclusion

The decline of the labour share, and the consequent increase of the capital share, is becoming increasingly prominent on the stage of 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 indeed the evolution of the ICT investment price together with job polarization and search frictions. Theoretically we predict a decline of the LS through two harmful mechanisms: an ICT-labour substitution effect and a search 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 that the elasticity is 1.18, implying that a decline of one percent of ICT price is associated to a increase of ICT capital stock over labour between 1.18%, generating a decline of the labour share. If we include hiring costs per employee into our model, the elasticity shrinks to 1.13 and we show that part of the explanatory power of the substitution effect is lost in favour of the search cost effect. Interestingly, it turns out that, for Europe, only the hiring cost per employee shapes downward more than in the US the evolution of the labour share.

In an additional 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 compositional labour market variables, by applying an extension of Binder and Offermanns (2007) that allows for stochastic shocks through a state-space specification. Our results show that the share of routine occupations (high-skill workers) is positively (negatively) associated with the elasticity of substitution between labour and ICT. This result connects in a direct way the job polarization phenomenon 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:

$$\mathscr{L} = \left\{ \beta \left[\alpha K_I^{\frac{\varepsilon-1}{\varepsilon}} + (1-\alpha) N^{\frac{\varepsilon-1}{\varepsilon}} \right]^{\frac{\varepsilon(\sigma-1)}{(\varepsilon-1)\sigma}} + (1-\beta) K_{NI}^{\frac{\sigma-1}{\sigma}} \right\}^{\frac{\sigma}{\sigma-1}} - wN - cV$$
$$- p_I I_I - p_{NI} I_{NI} + \lambda_1 [V q(\theta) - Ns]$$
$$+ \lambda_2 [\delta_I K_I - I_I] + \lambda_3 [\delta_{NI} K_{NI} - I_{NI}]$$

$$\partial N : \left(\frac{\sigma}{\sigma-1} \right) Y^{\frac{1}{\sigma}} \frac{\varepsilon(\sigma-1)}{(\varepsilon-1)\sigma} \beta (K_I L)^{\frac{\sigma-\varepsilon}{\sigma(\varepsilon-1)}} (1-\alpha) \frac{\varepsilon-1}{\varepsilon} N^{-\frac{1}{\varepsilon}} - w - \lambda_1 s = 0$$
$$Y^{\frac{1}{\sigma}} \beta (K_I L)^{\frac{\sigma-\varepsilon}{\sigma(\varepsilon-1)}} (1-\alpha) N^{-\frac{1}{\varepsilon}} = w + \lambda_1 s$$
$$\partial V : -c + \lambda_1 q(\theta) = 0$$
$$\lambda_1 = \frac{c}{q(\theta)}$$

By substituting λ_1 we obtain

$$Y^{\frac{1}{\sigma}} \beta (K_I L)^{\frac{\sigma-\varepsilon}{\sigma(\varepsilon-1)}} (1-\alpha) N^{-\frac{1}{\varepsilon}} = w + \frac{cs}{q(\theta)}$$
$$N^{\frac{1}{\varepsilon}} = \frac{Y^{\frac{1}{\sigma}} \beta (K_I L)^{\frac{\sigma-\varepsilon}{\sigma(\varepsilon-1)}} (1-\alpha)}{w + \frac{cs}{q(\theta)}}$$
$$N = \frac{Y^{\frac{\varepsilon}{\sigma}} \beta^{\varepsilon} (K_I L)^{\frac{\sigma-\varepsilon}{\sigma(\varepsilon-1)}\varepsilon} (1-\alpha)^{\varepsilon}}{(w + \frac{cs}{q(\theta)})^{\varepsilon}}$$

Now, with respect to ICT capital

$$\partial K_I : Y^{\frac{1}{\sigma}} \beta (K_I L)^{\frac{\sigma-\varepsilon}{\sigma(\varepsilon-1)}} (\alpha) K_I^{-\frac{1}{\varepsilon}} = -\lambda_2 \delta_I$$
$$\partial I : -p_I - \lambda_2 = 0$$
$$\lambda_2 = -p_I$$

By substituting λ_2 we obtain

$$K_I = \frac{Y^{\frac{\varepsilon}{\sigma}} \beta^{\varepsilon} (K_I L)^{\frac{\sigma-\varepsilon}{\sigma(\varepsilon-1)}\varepsilon} \alpha^{\varepsilon}}{(p_I \delta_I)^{\varepsilon}}$$

We use the first order condition for capital ICT to substitute $Y^{\frac{\varepsilon}{\sigma}} \beta^{\varepsilon} (K_I L)^{\frac{\sigma-\varepsilon}{\sigma(\varepsilon-1)}\varepsilon}$ 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 NonICT 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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