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

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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 as a function of labour market institutions and worker groups, we find that it is strongly positively correlated with a decline of routine occupations. An unconventional way to present 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

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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 technological progress, 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 new technologies give rise to nontrivial phenomena in the labour markets, namely a job polarization and occupational displacement. Given a scarce evidence on the effect of technology on factor shares, the motivation of this paper is to assess theoretically and empirically the impact of Information Communication Technology (ICT) on the labour income share. In particular, building on Karabarbounis and Neiman (2014), we focus on the price of ICT equipment and on the degree of substitution between ICT 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 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 labour share. The model ends up with two harmful mechanisms for the labour share, a labour-ICT substitution effect and a labour adjustment cost effect, that we assess by estimating the elasticity of substitution between ICT capital and labour. The results of the model under perfect labour markets reveal that the elasticity of substitution between labour and ICT ranges from 1.10 to 1.17, meaning that the downfall of ICT price affects negatively the labour share. When we consider hirings being costly, the elasticity shrinks to 1.07, implying that the substitution effects loses some of his explanatory power in favour of the adjustment cost effect. Interestingly, when we restrict our sample to Europe we find that the adjustment cost effect is the prevailing mechanism, given an elasticity of 1.02 and insignificantly different from one.

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, changes in employment protection legislation and wage coordination have been analyzed in their attempt to govern the technological progress or correct its undesired consequences (OECD, 2012). The main result of our analysis is that a reduction (increase) of routine occupations (high-skill workers) is associated with a higher elasticity of substitution. 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 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 LS for many developed countries. OECD (2012) reveals that the LS dropped in average by 5 percentage point between early 1990s and late 2000s, arguing that 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 LS, 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 LS decline is experienced by the manufacturing sector, potentially due to offshoring of labour-intensive production, and that changes in institutional setting are negligible.

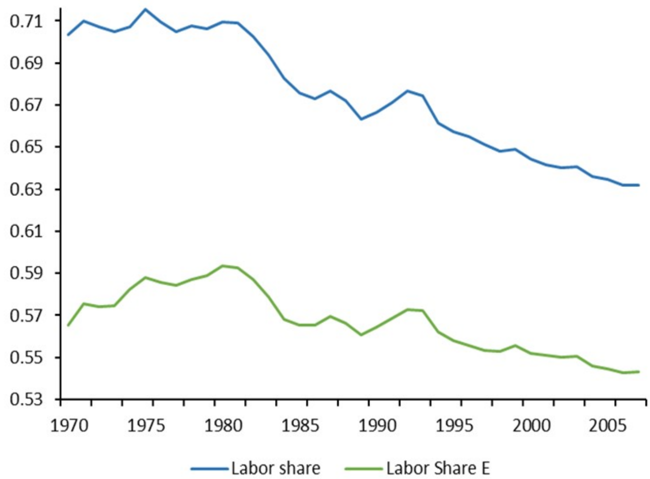

Figure 1: Aggregate labour share total labour force (blue line), aggregate labour share of employees (green line), computed as year fixed effects of a country and time fixed effects panel regression (source: EUKLEMS)

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 focuses 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[2]. It is worth to mention, however, that Karabarbounis and Neiman (2014), using EUKLEMS, show that the within component prevails.

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

[2]Karabarbounis and Neiman (2014), Elsby et al. (2013) and OECD (2012)

As discussed above, Karabarbounis and Neiman (2014) is the closest paper 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. 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.

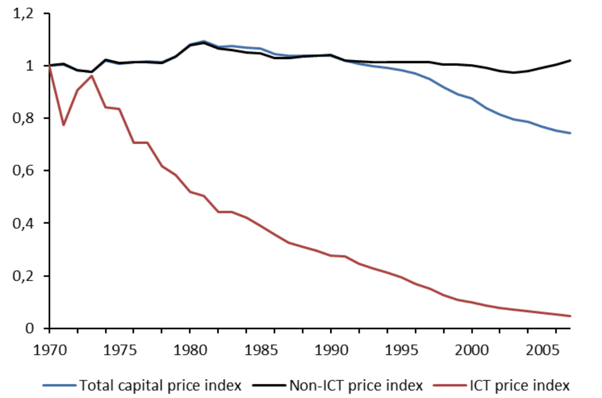

Figure 2: Price index per type of capital and total (average over the countries, 1970=1, source: EUKLEMS, own calculation)

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 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 it by making use of the nominal and real gross fixed capital formation index given by EUKLEMS dataset. Table 1

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

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

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 decline has been documented, among others, by Bosworth and Triplett (2000) and Jorgenson (2001), and explained by 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 ICT Adoption and Labour Markets

The impressive speed of adoption of ICT has raised several questions concerning its impact on the labour markets. The explanation for long time has been the capital-skill complementarity, argued 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. Autor et al. (2003), Autor et al. (2006) and Acemoglu and Autor (2011)

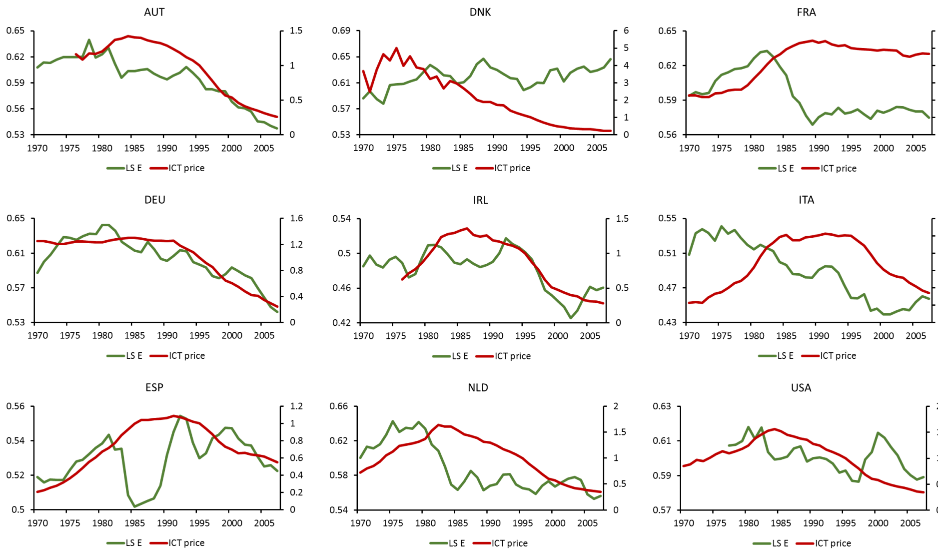

Figure 3: Employees labour share (green line, left axis), ICT index price (red line, right axis). Source: EUKLEMS

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. 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? 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[4] 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[5]. Figure 4 reports the percentage change of occupational employment shares for 4 time spells between 1993 and 2012 in the aggregate EU15[6]. 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 a worker, therefore only the hiring process of labour is affected by frictions, in terms of expenditures and time. Secondly, the production function has an unitary elasticity of substitution between the combined production of ICT capital with labour and non-ICT capital. We consider indeed that both ICT-capital and labour need a basic level of non-ICT capital, like machines and plants and, as consequence, changes in non-ICT price would not lead to changes in ICT and labour share. Hence, output is obtained with the combination of labour force N, ICT capital K_I and non-ICT capital K_{NI} in a production

[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

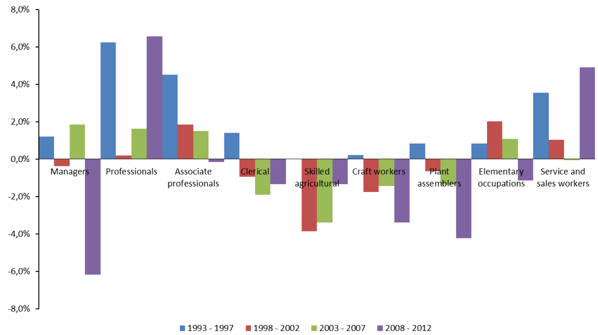

Figure 4: Changes in employment share per occupations. EU15 countries between 1993 and 2012 (percent, source: Eurostat)

function of the type

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

where α is a distribution parameter and $\varepsilon \in (0,\infty)$ is the elasticity of substitution between ICT capital and labour. Moreover, we consider job creation subjected to search costs c, namely the aggregate flow into employment in each period is given by a costly vacancy posting process and equals $V \cdot i$, where V is the number of vacancies and i 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

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

from which we get the steady state number of employees

$$N = \frac{Vi}{s}. \tag{3}$$

Capital input is ”hired” smoothly at the cost r that represents the overall 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)

$$\Pi = Y - wN - cV - (r_I + \delta_I)K_I - (r_{NI} + \delta_{NI})K_{NI}, \tag{5}$$

From that, we compute the first-order conditions:

$$\begin{aligned}
\partial N : \lambda_1 &= \sigma(1-\alpha)\frac{Y}{Y^*}N^{-\frac{1}{\varepsilon}} - w, \\
\partial V : \lambda_1 &= \tfrac{cs}{i}, \\
\partial K_I : \lambda_2 &= \sigma\alpha\frac{Y}{Y^*}K_I^{-\frac{1}{\varepsilon}} - r_I - \delta_I, \\
\partial \delta_I : \lambda_2 &= \frac{K_I\delta_I^2}{I_I}, \\
\partial K_{NI} : \lambda_3 &= (1-\sigma)\frac{Y}{K_{NI}} - r_{NI} - \delta_{NI}, \\
\partial \delta_{NI} : \lambda_3 &= \frac{K_{NI}\delta_{NI}^2}{I_{NI}},
\end{aligned}$$

where the λ_s are the Lagrange multipliers and $Y^* = \left(\alpha(K_{ICT})^{\frac{\varepsilon-1}{\varepsilon}} + (1-\alpha)N^{\frac{\varepsilon-1}{\varepsilon}}\right)$. By substituting the second condition into the first, we get the labour demand[7]

$$N = \frac{[\sigma(1-\alpha)Y]^\varepsilon}{\left[\frac{cV}{N} + w\right]^\varepsilon (Y^*)^\varepsilon}. \tag{6}$$

Equation (6) 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 substitutability with capital. In a context of high substitutability between labour and capital, namely with $\varepsilon > 1$, higher search costs 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.
Condition three and four give the demand for ICT capital

$$K_I = \frac{[\sigma\alpha Y]^\varepsilon}{P_I^\varepsilon (Y^*)^\varepsilon},$$

[7] To give an understandable meaning to the cs/i term in the optimization with respect to the vacancies, we multiply and divide it by N/v, so that we obtain $c\frac{sN}{iV}\frac{V}{N}$. In the steady state the flows of workers into and out of unemployment are equal, therefore we end up with the expression $\frac{cV}{N}$, namely the total cost of vacancies per employee.

where $P_I = r_I + \delta_I - \frac{K_I \delta_I^2}{I_I}$ and we use this expression to substitute $(Y^*)^\varepsilon$ into N, to get

$$N = \left[\frac{1-\alpha}{\alpha}\right]^\varepsilon \frac{P_I^\varepsilon K_I}{\left[\frac{cV}{N} + w\right]^\varepsilon}. \tag{7}$$

From this expression, we compute the labour income share

$$LS = \frac{w}{Y}\left[\frac{1-\alpha}{\alpha}\right]^\varepsilon \frac{P_I^\varepsilon K_I}{\left[\frac{cV}{N} + w\right]^\varepsilon}. \tag{8}$$

To conclude the theoretical setting we substitute condition five and six into equation (8), to get the final expression for the labour income share

$$LS = Hw\left(\frac{P_I}{C}\right)^\varepsilon \frac{k}{P_{NI}}, \tag{9}$$

where H is constant and equal to $(1-\sigma)\left(\frac{1-\alpha}{\alpha}\right)^\varepsilon$, P_{NI} has the same formulation as P_I above, $C = \frac{cV}{N} + w$ and k is the ratio between ICT and non-ICT stocks. The economic prediction of the model comes from the combination of the elasticity parameter ε, the costs and the quantities of the inputs:

- if $\varepsilon = 1$, the production function of labour and ICT is 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. Since we assumed an elasticity between ICT and non-ICT capital equal to one, both capital price and stock ratios cannot provoke a decline of the labour share. This suggests 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[8];

- if $\varepsilon \neq 1$, 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:

$$\frac{\partial LS}{\partial P_I} = Hw\varepsilon \frac{P_I^{\varepsilon-1}}{C^\varepsilon}\frac{k}{P_{NI}}. \tag{10}$$

  In case the elasticity 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

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

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.

This simple framework could describe what is happening to the factor income shares. Looking again at Figure , a decline of the price of ICT and an intense degree of substitution between ICT and labour could have played a role in shaping the evolution of the labour share downward.

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 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

$$cV = c_M M + c_U U, \tag{11}$$

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. This total flow into employment is available in the Eurostat database from 2010 to 2012 only[9]. 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 from the Data Warehouse of the German Federal Employment Agency, they amount to 46% of the matches[11].

[9] 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).

[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

As regards the cost of the matches c_M, we consider the vacancy cost, the adaptation cost (initial training and lower productivity) and the opportunity cost. The best we can do is to assume the first two categories as a constant ratio of the wage. Two studies for Germany give some support to this assumption: Muehlemann and Pfeifer (2016) and Carbonero and Gartner (2016) reveal that the cost per vacancy amounts to 4.8% in 2007 and 4.3% in 2014 of the yearly compensation per employee, respectively. Calibrating the vacancy and adaption costs according to Muehlemann and Pfeifer (2016), we set them together as 14% of the yearly compensation per employee.

We define the opportunity cost as the foregone profit arising if the filled vacancy becomes productive later in time than expected by the employer. Using the German Job Vacancy Survey (JVS) of the Institute for Employment Research (IAB), we detect 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 only the vacancy cost and the opportunity cost. The first is computed using the average duration of a failed vacancy, 140 days according to the JVS, and calibrated as 6% of the annual compensation per employee. The second amounts to the whole annual foregone profit, assuming that a vacancy that does not lead to a match is not followed by a new vacancy[12].

Finally, in order to assess the degree of job polarization, we use the Eurostat dataset on employment per occupation. This dataset covers all the European countries we selected, while for the US we rely on the Laborsta dataset from ILO. Finally, concerning the labour market institutions, the EPL index comes from the OECD dataset and the degree of wage coordination from the ICTWSS[13].

[12] As a robustness check, we compute the cost of unsuccessful vacancies in a more cautious way. From the JVS, 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 in the first round and the start of the employment relationship in the second round. For the remaining 21% of the unfilled vacancy we count as opportunity cost the period between the expected filling and the rest of the year. Given the assumption above, the cost resulting from this computation represents a lower bound. The estimates from this computation do not bring to different conclusions.

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

6 Model 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

$$lnLS_{it} = a_i + \varepsilon ln\frac{P_{I,it}}{w_{it}} + ln\frac{w_{it}k_{it}}{P_{NI,it}}, \tag{12}$$

$$lnLS_{it} = a_i + \varepsilon ln\frac{P_{I,it}}{C_{it}} + ln\frac{w_{it}k_{it}}{P_{NI,it}}. \tag{13}$$

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. Columns 1, 2 and 3 refer to equation (12), where we assume frictionless labour markets. The elasticity is about 1.17 and significantly different from 1. Given the different sample length of the time series of job flows, we report in column 2 the estimate of ε for the same years in which we have data on job flows; the elasticity is significantly higher than one at 1.10. 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. Column 3 will be treat below when we refer to the effect of hiring costs in Europe and in the US.

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**	**5**
			Europe only		**Europe only**
ε	1.17	1.10	1.07	1.07	1.02
	(0.010)	(0.011)	(0.012)	(0.016)	(0.016)
Frictions	No	No	NO	Yes	Yes
Obs	323	196	165	196	165
R^2	0.98	0.98	0.98	0.97	0.97

We turn now to the model that accounts for the hiring costs. With this exercise, we can measure 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 (13) are displayed in the last 2 columns. In column 4 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 1.07, 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 (9) firstly the smallest (1.07) and then the largest (1.10) 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

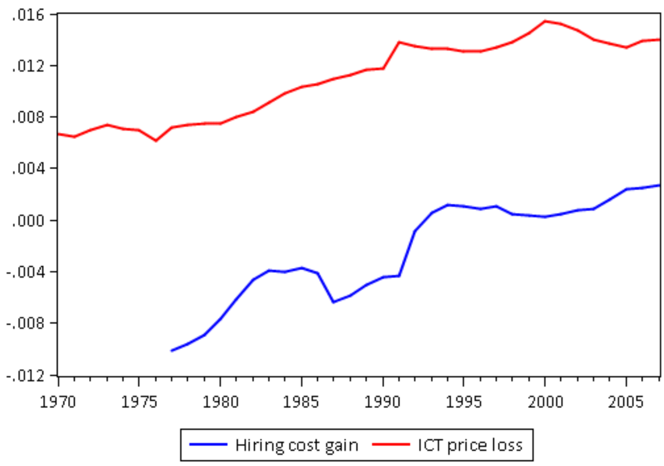

Figure 5: Gain in the predictive power of hiring costs (blue line) vs the loss of predictive power of ICT price (red line) (own calculation)

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 likely explained by the adjustment cost effect. Lastly, in the attempt of finding any structural difference between Europe and the US, in column 5 we estimate ε without the US; interestingly, the elasticity falls into the neighborhood of 1 and the Wald test does not reject the null hypothesis of a ε equal to one. This implies that, in Europe, the costly process of hiring the labour input explains most of the decline of the labour share and that the ICT adoption plays minor or no role.

The second part of the empirical analysis is addressed to verify to what extent the impact of ICT on the LS varies with a set of country-specific labour market variables. On the one hand, OECD (2012) reports mixed evidence on the role of firing restrictions and wage setting schemes on the labour share, on the other hand we know that the substitution effect hits mainly routine occupation and fosters high-skill workers. Therefore, we interact our elasticity parameter from equation (10) with four labour market variables, modelling it as follows

$$\varepsilon = \beta_0 + \beta_1 epl + \beta_2 routine + \beta_3 highskill + \beta_4 coord \tag{14}$$

where *epl* is the employment protection legislation index, *routine* is the employment share of routine occupations, *highskill* is the employment share of highskill workers and *coord* is the wage coordination index[14]. Results are reported in Table 3. The estimates of the interaction terms have no statistical significance but the high-skill variable, that is however difficult to interpret because high-skill workers should gain from a higher elasticity of substitution between technology and labour. We take each of the four variables out and it turns out that, after having neglected *epl*, we get some interesting results[15]. In particular, a lower employment share of routine occupations is associated with a higher elasticity of substitution between labour and ICT equipment. This is an evidence of the presence of a job polarization, namely that routine occupations are those who mostly suffer the substitution with capital in terms of employment. The coefficient on the degree of wage coordination is interesting as well. Given that the variable *coord* ranges from 5 (wage bargained at central level) to 1 (wage bargained at firm level), the result implies that a wage bargained at the highest institutional level is correlated with a lower elasticity of substitution. This conclusion is consistent with the claim that the ICT-labour substitution is a between-industry phenomenon.

[14] The measure ranges from 5 (centralized bargaining) to 1 (firm level bargaining).

[15] The *epl* index is quite constant over time and since we estimate the regression counting for country fixed effects, the relative coefficient is rather meaningless.

Table 3: Modification of equation (12) with interactions, country FE, robust SE. Dependent variable: logarithm of LS

Interactions with elasticity	ε	SE	ε	SE
ε x epl	0.001	0.003	–	–
ε x routine	0.074	0.052	-0.228^{***}	0.069
ε x highskill	-0.121^{**}	0.058	0.194^{***}	0.065
ε x coordination	-0.002	0.002	-0.009^{***}	0.003

Significance levels: $*$, $**$ and $***$ indicate significance at 1%, 5% and 10%

7 Conclusion

The decline of the labour share, and the consequent increase of the capital share, is taking more and more space on the stage of the 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 the technological progress and the labour markets. We consider indeed the evolution of the ICT investment price together with a job polarization and search frictions. Theoretically we predict a decline of the LS through a substitution effect between ICT capital and labour as well as with an employment adjustment cost effect and we test the plausibility of the two mechanisms by estimating the elasticity of substitution. What we find is that the elasticity of substitution between ICT capital and labour ranges between 1.10 and 1.17, implying that a decline of one percent of ICT price is associated to a increase of ICT capital stock over labour between 1.10% and 1.17% and generates a decline of the labour share. If we include hiring costs into our model, the elasticity shrinks to 1.07 and part of the explanatory power of the substitution effect is lost in favour of an adjustment cost effect. Interestingly, it turns out that, for Europe, only the hiring costs shape the evolution of the labour share.

Lastly, in the attempt of analysing the determinants of the ICT-labour elasticity, we model it as a function of country-specific institutional and compositional labour market variables. We show that a decline of routine occupations and an increase of high-skill workers are associated with a higher elasticity of substitution between labour and ICT. This result reveals, from a different perspective, the presence of the job polarization phenomenon. Concerning the institutional variables, the employment protection legislation seems to be negligible, while a wage coordination at central level has a strong negative correlation with the elasticity of substitution, consistent with the between-industry nature of the phenomenon.

8 Appendix

We derive the first order conditions from:

$$\begin{aligned}
\mathscr{L} = & \left[\left(\alpha(K_I)^{\frac{\varepsilon-1}{\varepsilon}} + (1-\alpha)N^{\frac{\varepsilon-1}{\varepsilon}}\right)^{\frac{\varepsilon}{\varepsilon-1}}\right]^{\sigma} (K_{NI})^{1-\sigma} - wN - cV \\
& - (r_I + \delta_I)K_I - (r_{NI} + \delta_{NI})K_{NI} + \lambda_1[\frac{Vi}{s} - N] \\
& + \lambda_2[K_I - \frac{I_I}{\delta_I}] + \lambda_3[K_{NI} - \frac{I_{NI}}{\delta_{NI}}]
\end{aligned}$$

$$\begin{aligned}
\partial N : & \left(\frac{\sigma\varepsilon}{\varepsilon-1}\right)(Y^*)^{\frac{\sigma\varepsilon}{\varepsilon-1}-1}\left(\frac{\varepsilon-1}{\varepsilon}\right)(K_{NI})^{1-\sigma}(1-\alpha)N^{\frac{\varepsilon-1}{\varepsilon}-1} - w - \lambda_1 = 0 \\
& \sigma(Y^*)^{\frac{\sigma\varepsilon}{\varepsilon-1}}(K_{NI})^{1-\sigma}(Y^*)^{-1}(1-\alpha)N^{-\frac{1}{\varepsilon}} - w - \lambda_1 = 0 \\
& \lambda_1 = \sigma(1-\alpha)\frac{Y}{Y^*}N^{-\frac{1}{\varepsilon}} - w \\
\partial V : & - c + \lambda_1 \frac{i}{s} = 0 \\
& \lambda_1 = \tfrac{cs}{i}
\end{aligned}$$

By substituting λ_1 we obtain

$$\begin{aligned}
\tfrac{cs}{i} + w &= \sigma(1-\alpha)\frac{Y}{Y^*}N^{-\frac{1}{\varepsilon}} \\
N^{\frac{1}{\varepsilon}} &= \frac{\sigma(1-\alpha)Y}{(\frac{cs}{i} + w)Y^*} \\
N &= \frac{[\sigma(1-\alpha)Y]^{\varepsilon}}{\left[\frac{cs}{i} + w\right]^{\varepsilon}(Y^*)^{\varepsilon}}
\end{aligned}$$

Now, with respect to ICT capital

$$
\begin{aligned}
\partial K_I : & \sigma \left(Y^*\right)^{\frac{\sigma\varepsilon}{\varepsilon-1}} \left(K_{NI}\right)^{1-\sigma} \left(Y^*\right)^{-1} \alpha K_I^{-\frac{1}{\varepsilon}} - r - \delta_I - \lambda_2 = 0 \\
& \lambda_2 = \sigma\alpha \frac{Y}{Y^*} K_I^{-\frac{1}{\varepsilon}} - r - \delta_I \\
\partial \delta_I : & - K_I + \lambda_2 \frac{I_I}{\delta^2} = 0 \\
& \lambda_2 = \frac{K_I \delta^2}{I_I}
\end{aligned}
$$

By substituting λ_2 we obtain

$$
\begin{aligned}
\frac{K_I \delta^2}{I_I} + r + \delta_I = \sigma\alpha \frac{Y}{Y^*} K_I^{-\frac{1}{\varepsilon}} \\
K_I = \frac{[\sigma\alpha Y]^\varepsilon}{\left[\frac{K_I \delta^2}{I_I} + r + \delta_I\right]^\varepsilon (Y^*)^\varepsilon}
\end{aligned}
$$

We use the first order condition for capital ICT to substitute $(Y^*)^\varepsilon$ in N

$$
\begin{aligned}
(Y^*)^\varepsilon &= \frac{[\sigma\alpha Y]^\varepsilon}{\left[\frac{K_I \delta^2}{I_I} + r + \delta_I\right]^\varepsilon K_I} \\
N &= \frac{[\sigma(1-\alpha)Y]^\varepsilon}{\left[\frac{cs}{i} + w\right]^\varepsilon} \frac{\left[\frac{K_I \delta^2}{I_I} + r + \delta_I\right]^\varepsilon K_I}{[\sigma\alpha Y]^\varepsilon} \\
&= \left[\frac{1-\alpha}{\alpha}\right]^\varepsilon \frac{\left[\frac{K_I \delta^2}{I_I} + r + \delta_I\right]^\varepsilon K_I}{\left[\frac{cs}{i} + w\right]^\varepsilon}
\end{aligned}
$$

As a consequence, the labour share as in equation (8) is:

$$
LS = \frac{w}{Y} \left[\frac{1-\alpha}{\alpha}\right]^\varepsilon \frac{\left[\frac{K_I \delta^2}{I_I} + r + \delta_I\right]^\varepsilon K_I}{\left[\frac{cs}{i} + w\right]^\varepsilon}
$$

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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