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Technology and Labor Regulations

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Abstract

Many low skilled jobs have been substituted away for machines in Europe, or eliminated, much more so than in the US, while adoption of advanced technologies at the “top”, i.e. at the high-tech sector, is faster in the US than in Europe. This paper suggests that this can be a result of different labor market policies in Europe and the US. European countries reduce wage flexibility and inequality through a host of labor market regulations, like binding minimum wage laws, permanent unemployment subsidies, firing costs, etc. Such policies create incentives to develop and adopt labor saving capital intensive technologies at the low end of the skill distribution. At the same time technology in the US is more skill biased than in Europe, since American skilled wages are higher.

1. Introduction

It is close to impossible to find a parking attendant in Paris, Frankfurt or Milan, while in New York City they are common. When you arrive even in an average Hotel in an American city you are received by a platoon of bag carriers, door openers etc. In a similar hotel in Europe you often have to carry your bags on your own. These are not simply trivial traveler's pointers, but indicate a deeper and widespread phenomenon: low skilled jobs have been substituted away for machines in Europe, or eliminated, much more so than in the US, while technological progress at the "top" i.e. at the high-tech sector is faster in the US than in Europe. Why?

This paper suggests that an important difference between Europe and the US that leads to such technological differences lies is their different labor market policies. Traditionally, since the seventies at least, European countries have kept wage flexibility and wage inequality low through a host of labor market regulations, like binding minimum wage laws, permanent unemployment subsidies, firing costs, etc.¹ These policies create incentives to adopt labor saving capital intensive technologies at the low end of the skill distribution. At the same time technical progress in the US is more skill biased than in Europe, since American skilled wages are higher.

There are only a few ways to model differential technology adoption across countries. One is to assume that it is costly, like Parente and Prescott (1995). This approach may help in understanding gaps between rich and poor countries, but it does not fit our case, since if adoption costs in Europe were higher, we should observe less technical progress in all sectors, which is not the case. Basu and Weil (1998) and

¹ In the last few years there have been some reforms of labor markets in several European countries. How these will unfold remains to be seen, but job creation in Europe has immediately picked up in response to those changes. See Alesina and Giavazzi (2007) for discussion.

Acemoglu and Zilibotti (2001) suggest instead that technology adoption depends on supplies of factors of productions, as different technologies fit better different factors of production. But as we show in the paper, this approach cannot account for the observed differences between Europe and the US. Actually it implies that the region with more skill biased technical change should be the one with a lower skill premium. We therefore resort to a third approach, following Champernowne (1963) and Zeira (1998, 2006), which models technological change as substituting labor by machines. According to this approach technological innovations reduce labor but require purchasing machines, namely increasing capital. Hence, such technological innovations are invented and adopted only if wages are sufficiently high, so that they reduce the cost of production.

In this paper we consider an extension of this approach to a model of two sectors, skilled and unskilled, and show that the wage in each sector determines the technology level in that sector. The model allows the US and Europe to differ in their supplies of skill and in their labor market policies. The model then shows that greater labor regulation in Europe, in the form of unemployment benefits, amongst others, leads to reduction in the skill premium in Europe, to less skill-biased technical change, but also to more technical progress in the unskilled sector.

Different labor market policies in the US and in Europe have already been the focus of much economic research, as an explanation to divergence in unemployment rates from the seventies onward.² But unemployment has been just part of the story. The number of work hours per person has steadily declined in Europe (especially France,

² See Blau and Kahn (1996, 2002) and Freeman and Katz (1995). Blanchard and Wolfers (2000) and recently Ljungqvist and Sargent (2006) amongst many others also point towards labor regulation and especially firing costs as the major explanation of recent development of European unemployment but not directly through the technological channel.

Germany and Italy) since the mid seventies relative to the US. Alesina, Glaeser and Sacerdote (2005) argue that the main explanation to it is union imposed work regulations and employer/union collective agreements on hours worked.³

Many economists have attributed the large rise in the wage skill differential in the US to skill biased technical change.⁴ This paper suggests that both the rise of wage inequality and the skill biased technical change could have been to some extent a result of a third process, the deregulation of markets in the US and the decline in labor unions' strength. It therefore raises the hypothesis of some reverse causality, namely that the rise of the wage differential in the US has contributed to skill biased technical change. At the very least the technological revolutions in the US would have been seriously impeded if the labor market environment would have been similar to that of Europe, or with stronger unions and less deregulation.

The paper stresses the idea that a high cost of labor may lead to labor saving technologies. Some traces of this idea already appear in other studies. Blanchard (1997) mentions substitution of labor by capital as one of the explanations for high unemployment in Europe. Caballero and Hammur (1998) use a similar idea but they do not focus on the low versus high skill differences. Beaudry and Collard (2001) investigate how endogenous changes in an AK technology may affect the employment- productivity trade-off and explain the degree of convergence across industrial economies. Saint Paul (2006) studies the effect of changes in technologies on distribution amongst factors.

³ Alesina et al (2005) also discuss additional explanations, like the increase in marginal tax rates, emphasized by Prescott (2004), and preference for leisure, stressed by Blanchard (2004). They conclude that while these other explanations also play some roles, the lion's share is due to the direct and indirect effects (via social multipliers) of labor regulations.

⁴ See Davis and Haltwinger (1991), Katz and Murphy (1992), Bound and Johnson (1992), Juhn, Murphy, and Pierce (1993), Berman, Bound and Grilliches (1994), Greenwood and Yorukoglu (1997), Acemoglu (1998, 2003), and Berman, Bound and Machin (1998).

An important aspect of this idea is that although the new technologies substitute labor by capital, the two factors of production are highly complementary. Producing some tasks by machines instead of labor enables workers in the remaining tasks to be more productive. Note that the substitution might even be of only part of the work done by a single worker, so that even the same worker can become more productive. An accountant who used to do calculations by hand in the past and does them with a computer, can process more cases as a result.

The paper is organized as follows. Section 2 presents the basic model. Section 3 compares the results to some alternative literatures. Section 4 presents extensions to other types of labor market regulations. Section 5 discusses some empirical implications of the model. The last section concludes and the appendix contains mathematical derivations of some results.

2. A Model of Technology and Labor Regulation

2.1 The Set-Up

The population in this economy lives in overlapping generations each of size 1. An individual is born to a single parent, lives two periods and has a single offspring. Individuals can work in first period of life only either as skilled or as unskilled. If an individual is born to a skilled parent learning is costless, but if born to an unskilled parent learning is infinitely costly. As a result the groups of skilled and unskilled are fixed over time.⁵ Denote by L_n the share of unskilled and by L_s be the share of skilled, so that: $L_n + L_s = 1$. In addition to being skilled or unskilled each person has individual efficiency e ,

⁵ This assumption can be relaxed to get mobility between skilled and unskilled. The main results of the model are not altered.

which is random, distributed uniformly between zero and 1, and is independent of whether the individual is skilled or unskilled. People derive utility from consumption in the two periods of life where $\rho > 0$:

$$(1) \quad \log(c_y) + \frac{\log(c_o)}{1 + \rho},$$

There is a single final good in the economy, which is used for both consumption and investment and is produced by two intermediate goods, the skilled good S and the unskilled N , using the following production function:

$$(2) \quad Y = S^\alpha N^{1-\alpha}.$$

The skilled good is produced by infinite tasks, or infinite intermediate goods $i \in [0,1]$ according to the following Cobb-Douglas production function:

$$(3) \quad \log S = a + \int_0^1 \log s(i) di.$$

Each i can be produced by one of two potential technologies. One is a manual technology, where a unit of i is produced by 1 efficiency unit of skilled labor. The second technology produces i by a machine, of size or cost $k(i)$ and it can replace the worker and produce a unit of i as well. Capital, namely machines, is fully depreciable within 1 period. Development or adoption of a new technology imbedded in a machine is costless. Hence, the only cost of the industrial technology is the cost of the machine. It is assumed that this cost $k(i)$ is rising with i .⁶ To solve the model analytically we use the following specification:

$$(4) \quad k(i) = \frac{1}{1-i}.$$

⁶ This is just an ordering assumption and has no effect on the analysis.

The unskilled good is produced by a similar production function:

$$(5) \quad \log N = a + \int_0^1 \log n(i) di.$$

Each unskilled intermediate good is produced either by one efficiency unit of unskilled labor or by a machine of size $k(i)$, where the function k is the same as in (4).⁷

The economy is open to capital mobility and small, so that the world interest rate is given and equal to r , and the gross interest rate is $R = 1 + r$. The economy trades only in the final good, and not in skilled, unskilled and intermediate goods. Also assume that educated people work as skilled but can work as unskilled as well, while people without education (children of unskilled) cannot work as skilled.⁸ Those without jobs are entitled to an unemployment compensation of v times the wage of unskilled, where $v < 1$, which is financed by a tax on income, at a fixed rate t . The tax is paid on the transfer payments as well and the government budget is balanced.

2.2 Technology Adoption

Denote by w_n (w_s) the gross wage rate per efficiency unit of an unskilled (skilled) worker.

First, a skilled intermediate good is produced by machines, if:

$$w_s \geq Rk(i) = \frac{R}{1-i}.$$

Hence all skilled intermediate goods $i \leq f_s$ are produced by machines, where the

technological frontier for skilled workers, f_s , is determined by:

$$(6) \quad 1 - f_s = \frac{R}{w_s}.$$

⁷ We can assume that the sectors are not symmetric, where the cost of a machine that replaces a skilled worker is $b_s/(1-i)$, and the cost of a machine that replaces an unskilled workers is $b_n/(1-i)$. The qualitative results of the model in this case are the same.

⁸ This assumption only warrants that skilled wages are higher or equal than unskilled wages.

Similarly:⁹

$$(7) \quad 1 - f_n = \frac{R}{w_n}.$$

Let P_S be the price of the skilled good, and $p_s(i)$ be the price of the intermediate good i in the production of S . On the demand side we can use the first order conditions of profit maximization of producers of the final good, the skilled and the unskilled good. On the supply side prices of intermediate goods in the two sectors are equal to production cost, due to free entry and constant returns to scale. Hence:

$$(8) \quad p_s(i) = \begin{cases} \frac{R}{1-i} & \text{if } i \leq f_s \\ w_s & \text{if } i > f_s. \end{cases}$$

Prices of intermediate goods in the unskilled sector are similar. Equating demand and supply prices leads, as shown in the appendix, to the following equilibrium condition:

$$(9) \quad \alpha f_s + (1 - \alpha) f_n = a + \varepsilon - \log R,$$

where $\varepsilon = \alpha \log \alpha + (1 - \alpha) \log(1 - \alpha)$. We call equation (9) the “goods markets equilibrium condition.” It describes a trade-off between the technology frontiers in the two sectors.

Denote the wage ratio between the skilled and unskilled by I , as it reflects the degree of wage inequality in the economy. From conditions (6) and (7) we get that this wage inequality is related to the technology frontiers in the two sectors:

⁹ Note that conditions (6) and (7) require that wages are greater than R . If this does not hold $f=0$ and there is no industrialization in the sector. We do not dwell on this case as it is clearly remote from the advanced economies we analyze.

$$I = \frac{w_s}{w_n} = \frac{\frac{R}{1-f_s}}{\frac{R}{1-f_n}} = \frac{1-f_n}{1-f_s}.$$

Hence, we get the “labor market constraint:”

$$(10) \quad f_n = 1 - I + If_s.$$

Together, the equations (9) and (10) determine the equilibrium values of technologies adopted and wages in each sector given the wage ratio between the two sectors as in Figure 1.. The **G** curve describes the goods market equilibrium condition (9), while the **L** curve describes the labor market constraint (10). Since skilled workers can always switch and work as unskilled the wage ratio I satisfies: $1 \leq I < \infty$.

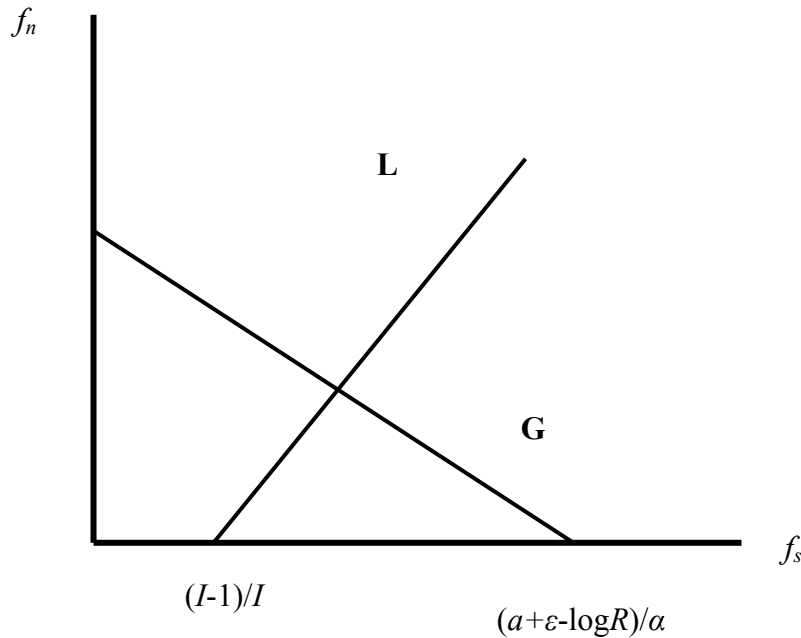


Figure 1: Determination of Technology Frontiers

A calculation of the equilibrium in Figure 1 yields the two technology frontiers:

$$(11) \quad f_s = 1 - \frac{1 + \log R - \varepsilon - a}{\alpha + (1 - \alpha)I},$$

and:

$$(12) \quad f_n = 1 - I \frac{1 + \log R - \varepsilon - a}{\alpha + (1 - \alpha)I}.$$

A sufficient condition for no corner solution at any wage inequality I between 1 and infinity is that the basic productivity a satisfies:

$$(13) \quad \alpha + \log R - \varepsilon \leq a \leq 1 + \log R - \varepsilon.$$

As wage inequality I increases, the curve **L** shifts down, reducing f_n and increasing f_s . Hence wage inequality induces technical adoption of machines in the skilled sector but reduces it in the unskilled sector. As a result, the wage of skilled workers rises and the wage of unskilled workers declines. A change in productivity a instead shifts the curve **G**. Hence, a country with higher productivity adopts more machines in both sectors, skilled and unskilled.

As shown above reducing wage inequality raises the wage of unskilled, but also lowers the wage of skilled. The reason is the complementarity between the skilled and unskilled goods in the production of final goods (2). Raising wages of unskilled reduces their input and thus reduces the unskilled good. This lowers the marginal productivity of the skilled good, its price and the skilled wage as well.

2.3. Equilibrium Wage Inequality

A worker chooses to work only if her earnings exceed the welfare payment. Hence an unskilled decides to work only if: $ew_n(1-t) \geq vw_n(1-t)$. The unskilled $[v, 1]$ work and their rate of unemployment is

$$(14) \quad u_n = v.$$

A skilled supplies labor if: $ew_s(1-t) \geq vw_n(1-t)$. Hence:

$$(15) \quad u_s = \frac{v}{I}.$$

We next derive the wage ratio I from the labor market equilibrium conditions for skilled and unskilled. The appendix shows how these conditions are derived from equating supplies and demands for labor in the two markets in terms of efficiency units:

$$(16) \quad \frac{L_s}{2} \left(1 - \frac{v^2}{I^2} \right) = \frac{\alpha RY}{w_s^2},$$

and:

$$(17) \quad \frac{L_n}{2} (1 - v^2) = \frac{(1 - \alpha)RY}{w_n^2}.$$

From these two conditions we derive the equilibrium value of wage inequality I :

$$(18) \quad I^2 = \frac{\alpha}{1 - \alpha} \frac{L_n}{L_s} (1 - v^2) + v^2.$$

Note that $\alpha L_n / [L_s (1 - \alpha)] \geq 1$. If this condition does not hold, the supply of skilled is too large and the wage ratio is lower than 1. In this case skilled workers turn to unskilled jobs, which pay a higher wage, and that drives wage inequality up to 1. Hence the actual L_s falls and this condition is restored. This condition implies both that wage inequality exceeds 1, and that it depends negatively on the degree of labor market regulation v .

2.4. The Effect of Unemployment Compensation

A country with a larger unemployment compensation v has a lower wage inequality I . As a result this country adopts less machines in the skilled sector, namely f_s is lower, but has more machines in the unskilled sector, namely f_n is higher and in this country w_s is

lower and w_n is higher. The effect of labor regulation on wage inequality works through the effective supplies of skilled and unskilled labor since unemployment compensation reduces the supply of unskilled by more than the supply of skilled. As a result it reduces the wage ratio, as due to equations (15) and (16) \hat{P}^2 is equal to $\alpha/(1-\alpha)$ times the ratio of the effective supply of unskilled to the effective supply of skilled in efficiency units.

3. Equilibrium and Welfare

In this section we complete the description of equilibrium, calculate the amounts of capital in the various sectors, calculate output and the tax rate and also try to examine why countries differ in their labor regulation, namely in v .

3.1. Capital across Sectors

Once the two technology frontiers are determined we can calculate the amounts of capital in the various sectors and in the two aggregate sectors. Capital in the skilled sector is:

$$(19) \quad K_s = \int_0^{f_s} \frac{s(i)}{1-i} di = f_s \frac{P_s S}{R} = \alpha f_s \frac{Y}{R}.$$

Capital in the unskilled sector is:

$$(20) \quad K_n = \int_0^{f_n} \frac{n(i)}{1-i} di = f_n \frac{P_n N}{R} = (1-\alpha) f_n \frac{Y}{R}.$$

If wage inequality declines, due to greater unemployment compensation, capital in the skilled sector K_s is reduced relative to output, while K_n increases relative to output. These are empirical implications that are explored in Section 5. Note also that the positive relationship between wage inequality and the relative capital in the skilled sector is observationally equivalent to capital-skill complementarity.

3.2. Output and the Government Budget

The aggregate unemployment rate is:

$$u = L_n v + L_s \frac{v}{I} = v \left[1 - L_s \left(1 - \frac{1}{I} \right) \right].$$

Aggregate output is calculated from the labor market equilibrium (15) and is equal to:

$$(21) \quad Y = \frac{L_s}{2\alpha R} \left(1 - \frac{v^2}{I^2} \right) w_s^2.$$

An increase in v reduces I and reduces w_s . Hence, labor market regulation v reduces output. It also increases unemployment. Note that a balanced budget requires:

$$(22) \quad tY = (L_n u_n + L_s u_s) v w_n = (L_n v + L_s v / I) v w_n.$$

If v is higher both unemployment is higher and the compensation per unemployed is higher, so that the overall amount of compensation, namely the right hand side of (22), is higher. Since output or income is lower, the tax rate must be higher.

3.3. Welfare Considerations

Consider the ex-ante expected utility of each person at birth, before her efficiency is known, as the correct measure of welfare. This is actually the average utility of skilled and of unskilled in each generation. In the appendix we show that ex-post utility is a linear transformation of the logarithm of net income. We therefore use log income as a measure of indirect utility. As shown in the appendix expected utility of unskilled is:

$$(23) \quad U_n = \log w_n + v + \log(1-t) - 1,$$

and expected utility of skilled is:

$$(24) \quad U_s = \log w_s + \frac{v}{I} + \log(1-t) - 1.$$

The effect of increasing ν is therefore mixed. On the one hand it has a direct positive effect on welfare, due to reducing the probability of poverty and low income. On the other hand it raises tax payments. Also, increasing welfare raises the unskilled wage, but lowers skilled wage. Hence it has different effects on the two types of workers.

The average welfare within a generation is a reasonable measure for ex-ante welfare, since the government does not transfer income across generations. Average ex-ante expected welfare, with equal weights to all, is equal to:

$$(25) \quad \text{AVG}(U) = L_n U_n + L_s U_s = (1 - L_s) U_n + L_s U_s.$$

We focus on this variable in order to find which level of labor regulation ν maximizes average welfare. We then examine whether the difference in labor regulation between Europe and the US can be explained by our model. Since the two countries differ in L_s , they might differ also in their optimal ν . Can that explain the observed difference in labor regulation and the resulting difference in wage inequality between the two regions?

The calculation of average utility is quite complicated and we resort to simulations. For that, we must specify reasonable values for the four parameters of the model: productivity a , the gross interest rate R , the share of skilled labor in production of the final good α , and share of skilled workers in the population L_s . We are aware of course that the model is very simplified and that our calculations are therefore only indicative and not very realistic.

Our choice of parameters is guided by our interest in comparing the US and Europe. Assuming that they are similar in interest rates and production parameters, our exercise centers on comparing outcomes across different values of L_s , keeping the other parameters fixed. For values of L_s we choose the percentage of the population between

ages 15 and 64 that had completed tertiary education in 1995. Thus for the US $L_s = 0.33$, and for Europe $L_s = 0.17$, where “Europe” is taken to be the average of France, Germany, and Italy.¹⁰ $R = 2$ is a realistic interest rate for a period of one generation. To set α note that the ratio of wages of college graduates and of high school graduates in the US has been 1.9 in the late 1990s, as shown by Autor, Katz, and Kearney (2005). Hence, α must be higher than .64, according to (18) and we set $\alpha = 2/3$. Finally, the productivity parameter a is set to satisfy condition (13) for an interior solution: $1.99 \leq a \leq 2.33$. So we set $a = \log(8) \sim 2.08$.

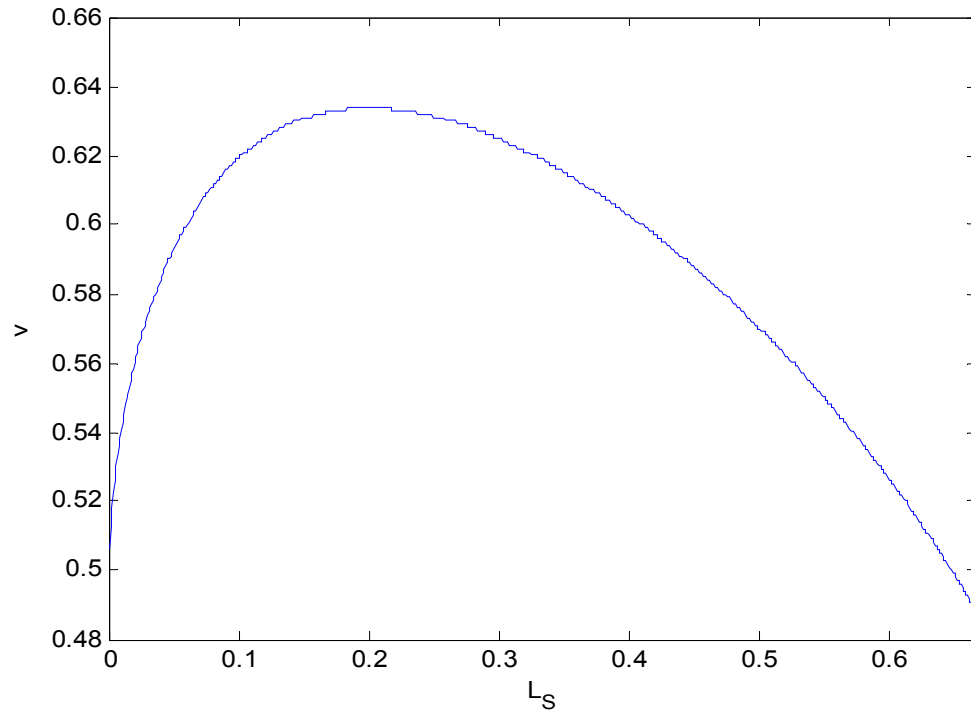


Figure 2: Optimal Unemployment Compensation

¹⁰ See Barro and Lee (2001).

Figure 2 shows how v , which maximizes $AVG(U)$, changes with the amount of skill. Figure 2 is drawn for $L_s \leq 2/3$, as implied by the constraint $\alpha L_n / (1 - \alpha)L_s \geq 1$, which is required by $I \geq 1$. Figure 2 shows that optimal v is positive, namely labor market regulation increases welfare by supplying insurance against being born with low efficiency.¹¹ Figure 2 also shows that optimal v does not change much with skill.

The locations of US and Europe on the curve in Figure 2 point at their optimal unemployment compensation. We can use equation (18) to calculate their implied v , namely the unemployment compensation which yields the observed wage inequality in the country, according to the model. The optimal v for the US should be .619. Its implied v , for a wage ratio of 1.9, is .383. The optimal v for Europe should be .633. Since the wage ratio in Europe is 1.4 according to Brunello, Comi, and Lucifora (2000), its implied v is .943. This simple exercise implies that unemployment compensation in the US is significantly below the optimal while in Europe it is significantly above the optimal. This means that our model cannot explain the differences in labor regulation, or social policies, between the US and Europe. In other words, the different supplies of skill are far from being the only source of difference between Europe and the US. There are also very different social values that lead to different choices on the two sides of the Atlantic.

4. Discussion

In this Section we discuss a few aspects of the model and its result. We first examine how our theory differs from other lines of research in the area of differences in technology

¹¹ We can also consider a Pareto-dominating policy, of means tested transfer payment. But such a policy fails if efficiency is not observed if the worker does not work. Then workers with low efficiency prefer to avoid work altogether. Under such moral hazard the policy in the model is indeed optimal.

across countries. We then discuss different types of labor market regulation and show that their effect is similar to that of unemployment benefits.

4.1. Comparison to Directed Technical Change

At this point we would like to compare our approach and results to an alternative literature, which also relates technical progress to supplies and prices of factors of production. This literature was originally called ‘induced innovations’, and was pioneered by Kennedy (1964), Samuelson (1965), Nelson and Phelps (1966) and others. A recent extension of this literature, called ‘directed technical change,’ has been developed in many papers, including Acemoglu (1998), Acemoglu and Zilibotti (2001), and Acemoglu (2003). When applied to our topic of skilled vs. unskilled labor, this literature can be described by use of the following production function:

$$Y = F[A_s L_s, A_n L_n].$$

A_s and A_n are the productivities of skilled and unskilled labor respectively. Technical change increases these productivities. While the original literature from the 1960s just imposed a constraint on the two types of technical change, the directed technical change literature explicitly adds innovations and their markets, following Romer (1990).

But however innovation is modeled, it is clear that this production function implies that technical progress for skilled labor is relatively higher if this factor is relatively more abundant and if its price is lower. Hence, the skilled-bias of technical change is inversely related to the skill premium.¹² This prediction is opposite to ours.

Thus our model and the induced innovation literature have conflicting predictions on the

¹² This inverse relationship is mitigated by technical change itself that increases the skill premium. But when two countries are compared, as in Acemoglu and Zilibotti (2001), this inverse relationship remains and technical change is skill-biased in the country that has a lower skill premium. This result holds even if the Acemoglu and Zilibotti analysis is applied with some necessary changes to the US and Europe instead of the North and South.

relationship between relative wages and technical change. The comparison between Europe and the US is therefore an example that can be used to distinguish between the two models.¹³

The intuitive explanation for the difference between the results of the two approaches is their different modeling of the relationship between labor and capital. While in our model technical change both replaces skill, in intermediates $[0, f]$, and complements it, in intermediates $(f, 1]$, in the directed technical change model capital only complements it.¹⁴ This is the reason why the two approaches have opposite predictions with respect to technical progress and wages.

4.2. Comparison to Factors' Substitution

Another relevant comparison of our model could be to the standard neoclassical model of substitution between labor and capital. Even in a model with a fixed technology, changes in labor regulation could lead to substitution of labor by capital in the skilled and unskilled sectors. But such a model misses two important points. One is of course the changes in technology across countries, which are the main focus of this paper.

According to our model not only capital replaces labor, but it also changes the production function at the same time. The second point is that the neoclassical model with fixed technology has different predictions with respect to the amounts of capital. In the neoclassical model without endogenous technology f_n and f_s are fixed parameters. It can be shown that although in many aspects the equilibrium of such an economy is different, equations (19) and (20) hold nonetheless. Hence, the ratio of capital in each sector to

¹³ We of course do not criticize here Acemoglu and Zilibotti (2001), which focuses on differences between the North and the South. Our claim is that to understand the differences between Europe and the US we need a different approach.

¹⁴ Interestingly, Acemoglu and Zilibotti (2001) have substitution between factors, but between skilled and unskilled workers in each intermediate good, but not between capital and labor.

output should be fixed according to the neoclassical model, while it should change with labor regulation in our model. As shown in Section 5 these ratios differ significantly both across countries and over time. This observation therefore does not fit the neoclassical model of factor substitution, but it fits our model of technical change.

4. 3. Other Forms of Labor Regulation

Unemployment compensations are not the only form of labor market policies. Amongst the most common are binding minimum wage floors, and various costs and legal prohibitions of firing. We claim that these policies yield qualitatively the same results as unemployment compensation, namely they reduce wage inequality, raise unskilled wage and lower skilled wage and thus bias technology toward the unskilled sector.

To study the effect of minimum wages we apply it to our basic model from Section 2. There is only one main assumption that needs to be changed, the assumption that worker's efficiency is known to all. Under this assumption all workers with efficiency below the minimum wage are fired. It means that the minimum wage policy hurts all and thus no one wants it. We assume instead that worker's efficiency is not known but can be observed by employers for only some of the workers. Hence only some of the workers with low efficiency are fired. The appendix shows that in this model minimum wages reduce wage inequality and induce unskilled bias technology.

The appendix also contains an analysis of the effect of firing costs on wages and technology. It shows that firing costs have a similar effect to that of unemployment benefits or minimum wages. Note though that both under minimum wages and under firing costs some workers become involuntarily unemployed. Hence, such policies are usually accompanied with some welfare payments, or unemployment benefits. In these

cases it does not affect the equilibrium if the amount of unemployment benefits is lower than the minimum wage.

All of the labor regulations described above reduce wage inequality. Often limiting wage inequality is a direct objective of labor unions and of governments, especially in Europe.¹⁵ Such policies yield similar results as the labor regulations described above, as can be inferred from the analysis of minimum wages in the appendix, which is equivalent to setting a bound on wage inequality. Another way to understand this issue is to consider a union that acts as a labor monopoly and sets higher unskilled wages. All these deviations from the free market wage inequality lead to unskilled biased technology.

5. Empirical discussion

We next discuss the empirical implications of the model with reference to some suggestive evidence drawn from comparisons between the US and Continental Western Europe (Europe in short).

5.1. Differences in Labor Market Regulation

Up to the mid seventies unemployment was lower in Europe than in the US and Europeans were working longer hours. After that everything changed: unemployment grew and remained much higher in Europe than in the US and hours worked per person fell in Europe while they remained roughly constant in the US. Figures 3 and 4 highlight these patterns. What happened? As for unemployment, a fairly accepted view goes as follows. The supply shocks of the seventies were accompanied by wage moderation in

¹⁵ For a discussion of Europeans' aversion to inequality and unions' policies to limit wage inequality it see Alesina and Glaeser (2004), Alesina, Di Tella and Mc Culloch (2004) and Blau and Khan (2002).

the US, while in Europe strong unions imposed real wage growth. At the same time European governments (often in consultations with unions) continued with the policies that started in the late sixties, of introducing and then reinforcing a host of labor market regulations such as binding minimum wage laws, firing costs and unemployment subsidies often unrelated to job search.¹⁶ As convincingly shown by Blanchard and Wolfers (2000), the interaction of this kind of labor institutions and those macroeconomic shocks generated persistent unemployment.¹⁷

Alesina, Glaeser and Sacerdote (2005) argue that the most important explanation for the decline in work hours is labor regulation and collective union agreements including pension regulations. A good portion in the lower work hours per person in Europe versus the US is due to lower participation in the labor force, especially amongst the very young and the very old.¹⁸ Regulations about required holiday, overtime, lower work week hours, have done the rest.

5.2. Differences in Wage Inequality

In the eighties and the nineties we observed not only differences in unemployment between the US and Europe but also differences in wage gaps.¹⁹ Table 1, reproduced from Blau and Khan (1996, 2002) shows the increase in wage dispersion in the US relative to Europe. In the eighties and nineties the ratio of wages in the 50-10 deciles increased by 13 per cent for men and by 18.6 per cent for women in the US. In Europe it

¹⁶ See Lazear (1990) and the detailed study of French labor institutions by Blanchard, Coehn and Nuveau (2005).

¹⁷ Subsequent work by Bertola Blau and Kahn (2002) confirms these results.

¹⁸ Alesina Glaeser and Sacerdote (2005) calculate that about one third of difference in work hours per person between France and Germany on one side and the US on the other is due to higher participation in the labor force in the US. Comparing US and Italy the same factors (labor force participation) explain more than half of the difference in work hours. Additional factors explaining lower work hours are marginal tax rates (Prescott (2004)) and preferences for leisure (Blanchard (2004)).

¹⁹ See Katz and Murphy (1992) for early work on relative supply of skilled versus unskilled labor.

increased only by 4 and 3 per cent respectively. In France and Germany it actually declined. In addition note how the difference in the wage dispersion between the US and Europe is much more pronounced at the bottom end of the wage scale. Namely, the US-Europe difference is much larger in the 50-10 ratios than in the 90-50 ones and union policies are more likely to affect wage dispersion in the bottom half rather than in the top half of the wage distribution. In fact Blau and Kahn (2002) conclude that union policies and labor market regulation are critical in explaining the difference in wage dispersion in the two sides of the Atlantic, after controlling for many other factors which may affect this difference.²⁰

5.3. Differences in Technology

Blanchard (1997) notes that after the shocks of the seventies European firms shifted to labor saving technologies which led to an increase in the capital labor ratio and after a period of adjustment, to higher profits. He shows that from 1980 to the late nineties capital labor ratios have been steadily and sharply increasing in Continental Europe, while they have been quite stable in Anglo-Saxon economies, as also shown in Figure 5. Along similar lines, Caballero and Hammur ((1998) report a positive correlation between the capital labor ratio and the degree of labor protection in OECD countries.

We have assembled some casual evidence that is consistent with the hypothesis that capital has substituted for low skill work. Comin and Hobijn's (2004) data set contains information on adoption of some technologies by 24 countries over the last 215 years. We compare US to France, Germany and Italy, the three largest Continental European countries. For most of the technologies in the data set it is unclear whether they are low skill or high skill labor saving, but for two cases we feel pretty confident.

²⁰ See also Gottschalk and Smeeding (1997) for a discussion of wage dispersion in OECD countries.

Figures 6 and 7 show the patterns of adoption of personal computers and of industrial robots in these countries. One could safely argue that computers substitute (and complement) high skill labor while robots substitute for low skill labor. The figures show that there are significantly more PCs per capita in the US than in the three European countries while there are significantly more robots per capita in the three European

Next we present data on capital in the skilled and unskilled sectors in the US and in our three representative European countries France, Italy and Germany. The data for the European countries are from the OECD, while the data for the US is from the BEA, as the OECD data do not contain capital amounts for the US.²¹ The division of sectors to skilled and unskilled is done according to share of skilled professions, where a sector with more than 50% skilled is defined as skilled.²² We then sum up net capital stocks in both types of sectors to get K_s and K_n .

From equation (19) we get that:

$$\frac{K_s}{Y} = f_s \frac{\alpha}{R}.$$

Hence, comparing the capital to output ratios across countries enables to compare the degree of skill-biased technology, assuming that the two regions face similar interest rates. Similarly from equation (20) we get:

$$\frac{K_n}{Y} = f_n \frac{1-\alpha}{R}.$$

This enables to compare unskilled-biased technology between the two regions. Figure 8 presents the ratios of capital to output in the skilled sectors in our four countries. It shows

²¹ The two data sets differ in their sector qualification, as the BEA data follow NICS while the OECD data follow SICS. We have matched the two data sets together.

²² The classification of sectors to skilled and unskilled is done by BLS data for 1989 and 1990.

that the level of technology in these sectors was higher in the US than in the European countries, except for Germany. Figure 9 presents the ratios of capital to output in the unskilled sectors and it clearly shows that unskilled biased technology in the US is below the European countries in recent decades. Furthermore, the two figures show that while skill-biased technology increased in the US in recent decades, unskilled-biased technology declined significantly at the same time.

Using plant level data, Lewis (2005) shows that the degree of adoption of automation technologies (thus of capital intensity) is higher in US cities that have received less immigration of low skill workers. He even uncovers de-adoption of automation technologies in cities that receive an especially large influx of immigrants.

5.4. Job Creation in Private and Public Sectors

One implication of our argument is that the ratio of high skilled jobs created in Europe relative to low skilled jobs should be higher than in the US. This is precisely what Pissarides (2006) finds. He argues that the Lisbon target for job creation in Europe will not be achieved because of sluggish creation of jobs in Europe in the labor intensive low skilled service sectors, which is where most job creation has occurred in the US and UK. Pissarides (2006) concludes that European countries have been successful at creating jobs in the “knowledge sectors”.....but have been unsuccessful at creating them in labor intensive....sectors” which is exactly one of the implications of our model.²³ This paper also shows a strong negative correlation between the level of labor market regulations and job creation in (low skilled) community service jobs (Figure 6 of Pissarides (2006)). Job creation in Europe would have been even lower and unemployment higher without the use of public employment to alleviate unemployment at relatively low skilled level.

²³ See Table 4 of Pissarides (2006) for evidence.

Often public job programs for “community service jobs” (as above) such as cleaning parks and roads assistance to elderly living at home alone are staffed by hiring individuals that would not be hired by the private sector.²⁴ Our model can easily account for this by redefining the unemployment subsidy as the wage of a public job.

6. Conclusions

After the seventies’ the performance of labor markets in Europe and in the US departed significantly in many aspects. In the US labor markets remained relatively unregulated and the US experienced a sharp increase in wage inequality, a stagnation of real wages for low skilled work, low unemployment and stability of hours worked per person. In Europe, on the contrary, labor regulation increased in the aftermath of the early seventies’ shocks. Unions’ policies targeted defending wages by imposing binding minimum wage laws and similar regulations. The result has been higher and persistent unemployment, lower hours worked per person and a much more equal wage distribution.

This paper shows how these developments in relative wages also influenced affected technical adoption in the two places. Lower wage gaps in Europe have led firms to switch to labor saving technologies at the low end of the skill distribution. Hence, low skilled labor has been substituted away by machines in Europe more than in the US. Obviously various exogenous developments in science and technology, like the invention of computers, play an important role. But the speed of adoption and of adjustment to new technologies depends on labor market regulations and policies.

²⁴ Evidence for that is also provided by Edin and Topel (1997), Bjorklund and Freeman (1997) and Kahn (1998a) for Norway and Sweden (see however Kahn (2000b) for some discussion of robustness); by Blau and Kahn (2000b) for Germany and by Alesina, Danninger and Rostagno (2001) for Southern Italy.

Appendix

Derivation of the Goods Market Equilibrium Condition

The first order condition for each intermediate good in the skilled sector is:

$$(A1) \quad p_s(i) = P_s \frac{\partial S}{\partial s(i)} = \frac{P_s S}{s(i)}.$$

Equating this demand price with the supply price in equation (8), deriving $s(i)$ and then substituting in the production function of the skilled good (3) we get:

$$\begin{aligned} \log S &= a + \int_0^1 \log \frac{P_s S}{p_s(i)} di = a + \log S + \log P_s - \int_0^{f_s} \log \frac{R}{1-i} di - \int_{f_s}^1 \log w_s di = \\ &= a + \log S + \log P_s - f_s \log R - (1 - f_s) \log w_s + \int_0^{f_s} \log(1-i) di. \end{aligned}$$

Using (6) and $\int_0^{f_s} \log(1-i) di = -(1 - f_s) \log(1 - f_s) - f_s$ we get that the price of the skilled good is equal to:

$$(A2) \quad \log P_s = f_s + \log R - a.$$

In a similar way it is shown that the price of the unskilled good is

$$(A3) \quad \log P_n = f_n + \log R - a.$$

While these prices reflect the supply side, from the demand side prices satisfy the following first order conditions:

$$\begin{aligned} P_s &= \frac{\partial Y}{\partial S} = \alpha S^{\alpha-1} N^{1-\alpha} = \frac{\alpha Y}{S}, \\ P_n &= \frac{\partial Y}{\partial N} = (1 - \alpha) S^\alpha N^\alpha = \frac{(1 - \alpha) Y}{N}. \end{aligned}$$

Substituting these first order conditions into the production function (2) we get the following constraint on the prices of the two goods:

$$(A4) \quad \alpha \log P_s + (1 - \alpha) \log P_n = \varepsilon,$$

where ε denotes $\alpha \log \alpha + (1 - \alpha) \log(1 - \alpha)$. Substitute (A2) and (A3) in (A4) and get:

$$\alpha f_s + (1 - \alpha) f_n = a + \varepsilon - \log R.$$

This is the goods markets equilibrium condition.

Derivation of the Labor Market Equilibrium Conditions

The supply of employed skilled labor in efficiency units is equal according to (15) to:

$$\frac{L_s}{2} \left(1 - \frac{v^2}{I^2} \right).$$

The supply of unskilled labor is equal according to (14) to:

$$\frac{L_n}{2} (1 - v^2).$$

The demand for skilled labor is equal to:

$$\int_{f_s}^1 s(i) di = \int_{f_s}^1 \frac{P_s S}{p_s(i)} di = (1 - f_s) \frac{\alpha Y}{w_s} = \frac{\alpha R Y}{w_s^2}.$$

The demand for unskilled labor is equal to:

$$\int_{f_n}^1 n(i) di = \int_{f_n}^1 \frac{P_n N}{p_n(i)} di = (1 - f_n) \frac{(1 - \alpha) Y}{w_n} = \frac{(1 - \alpha) R Y}{w_n^2}.$$

Equating the supplies and demands yields the equilibrium conditions (16) and (17).

Derivation of Expected Utilities

The ex-post utility of a person with net income j in first period of life is

$$\frac{2 + \rho}{1 + \rho} \log j + \frac{\log R + (1 + \rho) \log(1 + \rho) - (2 + \rho) \log(2 + \rho)}{1 + \rho}.$$

Hence, utility is a linear transformation of $\log j$. The expected log of income of a skilled worker before efficiency is realized is:

$$\int_0^v \log[v w_n (1 - t)] de + \int_v^1 \log[e w_n (1 - t)] de = \log w_n + \log(1 - t) + v - 1.$$

This proves equation (23). Ex-ante expected log income of skilled is calculated similarly.

Analysis of the Effect of Minimum Wages

Assume a similar model to the one in section 2, except for the following differences.

First, all skilled workers have efficiency 1. Second, unskilled workers have the same distribution of efficiency as in the benchmark model, but a worker's efficiency e is

unknown both to the worker and to the employer. It can be observed by the employer only if the worker is monitored and only a proportion m of workers is monitored. We also assume that unskilled firms are sufficiently large so that the distribution of workers' efficiencies within each firm is the same as the aggregate distribution. Clearly, despite the different levels of efficiency unskilled workers are paid the same wage w_n due to asymmetry in information. Finally, assume that there is minimum wage regulation that sets the wage of unskilled to be at some ratio with the skilled wage:

$$(A.5) \quad w_n = gw_s.$$

To derive the equilibrium we look at an employer who uses unskilled labor to produce an intermediate good. The employer knows the efficiency of m of the workers and fires a worker with efficiency e if: $ep_n(i) < w_n$. Hence, the upper bound for firing unskilled workers is $E_n(i)$, which is equal to: $E_n(i) = w_n/p_n(i)$. The unskilled workers who are left in production are therefore those who have higher efficiency or those who have not been monitored.

Next consider technology adoption. In the skilled sector technology depends on comparing the cost of machine production to the cost of a worker, which is also the cost of one efficiency unit. Hence, the technological threshold in the skilled sector is:

$$(A.6) \quad \frac{R}{1-f_s} = w_s.$$

In the unskilled sector a producer shifts to the industrial technology if the unit cost of producing by machines is lower than the average unit cost of producing by labor. Hence, the technology frontier at the unskilled sector is determined by:

$$(A.7) \quad \frac{R}{1-f_n} = \frac{m \int_{E_n(i)}^1 w_n de + (1-m) \int_0^1 w_n de}{m \int_{E_n(i)}^1 e de + (1-m) \int_0^1 e de} = 2 \frac{w_n - m \frac{w_n^2}{p_n(i)}}{1 - m \frac{w_n^2}{p_n^2(i)}}.$$

To derive the equilibrium price of an unskilled intermediate good which is produced labor, note that profits are driven to zero by free entry. Hence price equals average cost and it follows from (A.7) that:

$$(A.8) \quad p_n(i) = 2 \frac{w_n - m \frac{w_n^2}{p_n(i)}}{1 - m \frac{w_n^2}{p_n^2(i)}}.$$

Solving (A.8) shows that the price is equal to: $p_n(i) = p_n = xw_n$ where x is:

$$x = 1 + \sqrt{1 - m}.$$

Hence the technology frontier in the unskilled sector is described by:

$$(A.9) \quad \frac{R}{1 - f_n} = xw_n,$$

Given that the ratio between the unskilled and skilled wages is g due to wage compression, we get:

$$(A10) \quad f_s = 1 - gx(1 - f_n).$$

An increase in g reduces f_s and w_s and raises f_n and w_n . Hence, the effect of labor force regulation on technical change is the same as in the benchmark model. Note that without minimum wage regulation the free market equilibrium wage ratio, I_e is given by:

$$L_n \left(1 - \frac{m}{x} \right) = \frac{1 - \alpha}{\alpha} \frac{L_s}{x^2 I_e^2}.$$

If g is higher than the equilibrium wage ratio, which is the case if it is effective, there are two types of unemployment of unskilled. There are $mE_n = m/x$ fired workers, and there are also workers who are not hired at all, since the unskilled wage rate is too high.

Analysis of the Effect of Firing Costs

Assume that the model is similar to the benchmark model except for one difference. Individual efficiency e is unknown to the worker, but is observed by the employer on the job. Assume that an employer can fire a worker, but this act is costly and the firing costs are h in terms of the final good. Also assume that firms are sufficiently large so that the distribution of workers' efficiencies within each firm is the same as the aggregate distribution. First note, that due to asymmetric information, both skilled and unskilled wages are equal for all workers, irrespective of efficiency. Consider next an employer

who uses skilled labor to produce an intermediate good. Since the employer knows the efficiency of workers, he will fire those with efficiency e that satisfies: $ep_s(i) - w_s < -h$. Hence, the threshold for firing skilled workers $E_s(i)$ is determined by:

$$(A.11) \quad E_s(i) = \frac{w_s - h}{p_s(i)}.$$

The firing threshold in the unskilled sector is similar. It follows from (A11) that to find the threshold for firing we need to find the equilibrium price of the intermediate good, which is produced by skilled labor. Note that profits are driven to zero due to free entry and hence price equals average cost per unit produced, including firing costs:

$$p_s(i) = 2 \frac{(1 - E_s(i))w_s + E_s(i)h}{1 - E_s^2(i)}.$$

Together with (A.11) we get:

$$(A.12) \quad p_s(i) = p_s = w_s + \sqrt{h(2w_s - h)},$$

and:

$$(A.13) \quad E_s(i) = E_s = \frac{w_s - h}{w_s + \sqrt{h(2w_s - h)}} = 1 - \sqrt{\frac{2h}{p_s}}.$$

The results for unskilled goods are symmetric. Next, consider technology adoption. A producer shifts to industrial technology if the unit cost of producing by machines is lower than the average unit cost of producing by labor. Hence, the technological threshold is determined by:

$$(A.14) \quad \frac{R}{1 - f_s} = p_s.$$

The technological threshold in the unskilled sector is similar and in a similar way to the benchmark model we can derive the same “goods market equilibrium condition” as condition (9) in the benchmark model. In the Skilled sector we get:

$$(A.15) \quad \frac{\alpha Y}{L_s} = \frac{\sqrt{\frac{2Rh}{1 - f_s}} - h}{1 - f_s}.$$

The equilibrium condition in the market for unskilled labor is similar. Thus:

$$(A.16) \quad \frac{\sqrt{\frac{2Rh}{1-f_s}} - h}{1-f_s} = \frac{\alpha L_n}{1-\alpha L_s} \frac{\sqrt{\frac{2Rh}{1-f_n}} - h}{1-f_n}.$$

This labor market equilibrium condition constitutes a positive relationship between f_n and f_s . Hence, together with the “goods market equilibrium condition” it determines a unique general equilibrium, as can be described in a diagram similar to Figure 1. Using it we can show that a rise in firing costs h increases f_n and lowers f_s .

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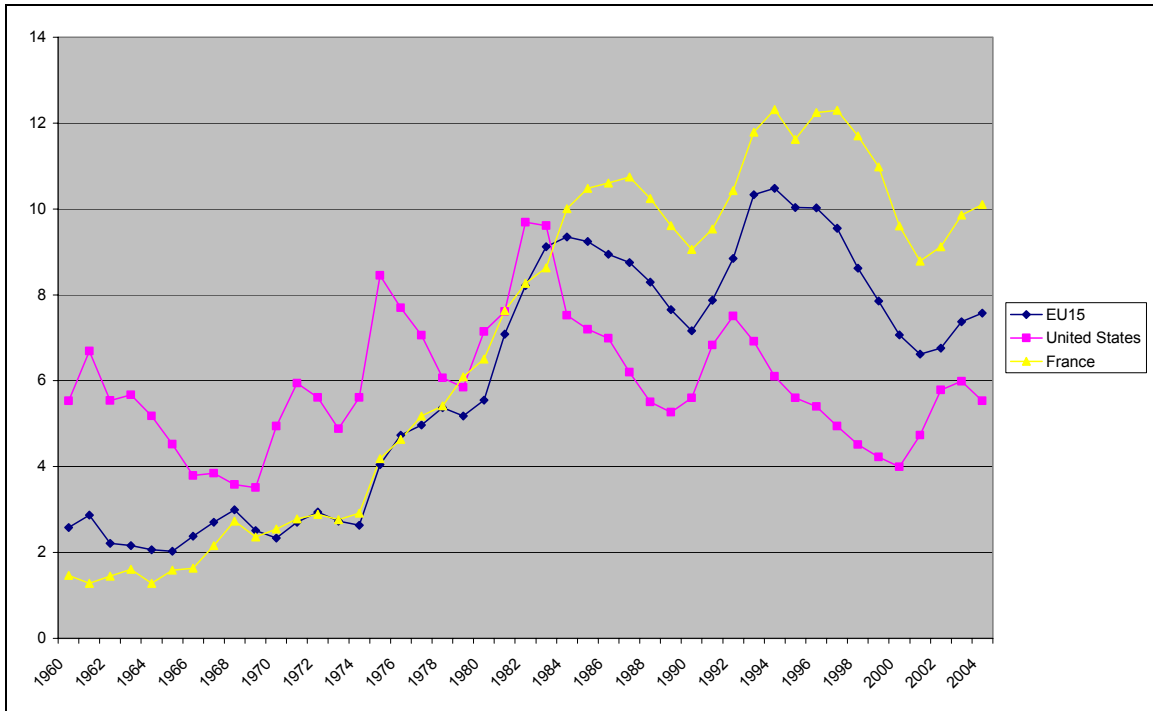
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Figure 3

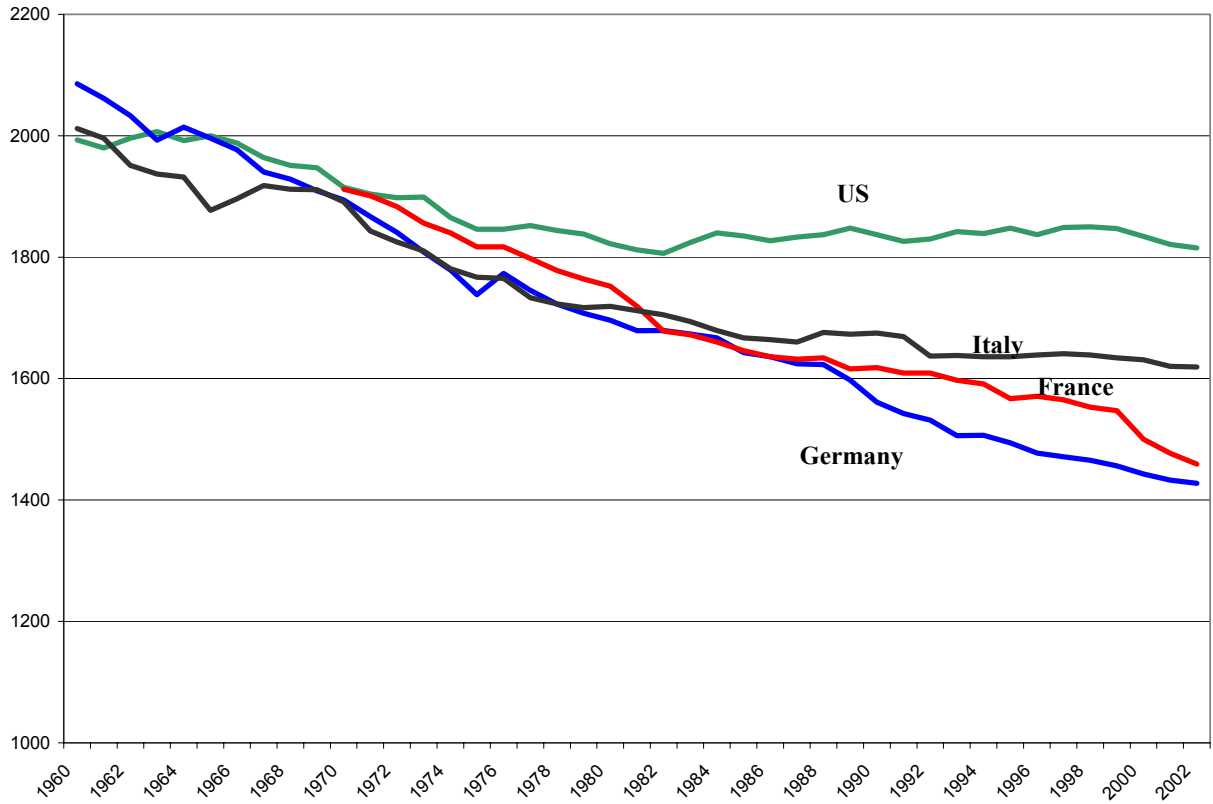
Unemployment Rate, 1960-2004 (%)



Source: OECD.

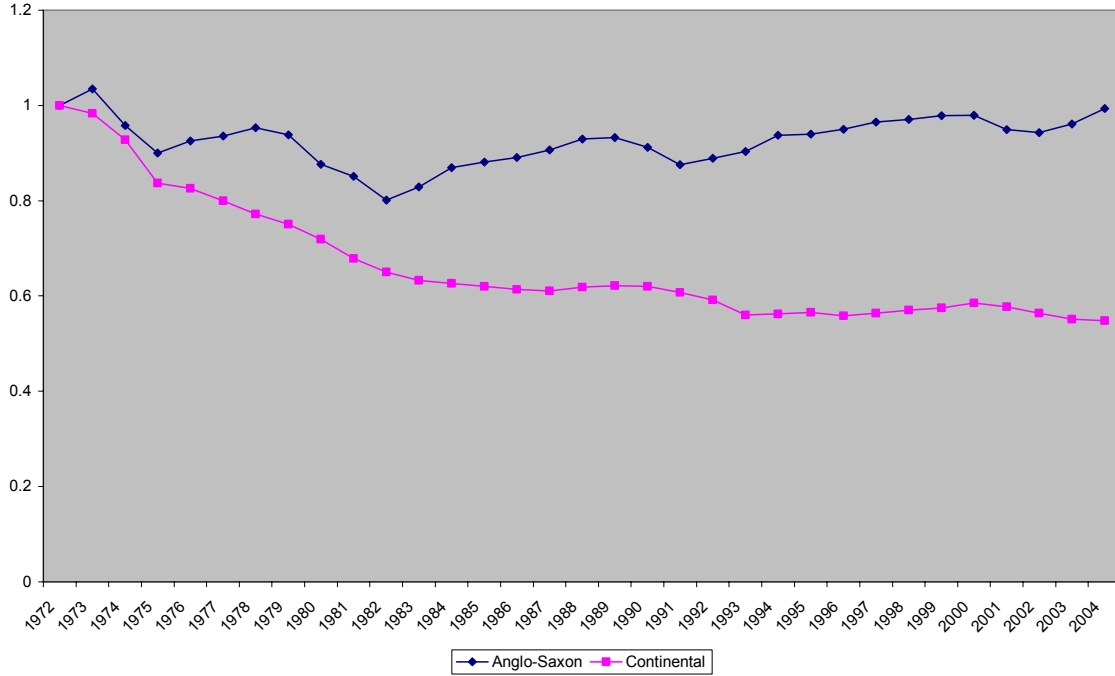
Note: EU15 corresponds to an unweighted average. Before 1977, not all countries from the EU15 are in the sample (as many as seven countries missing in some years); data from the Netherlands are available only until 2002.

Figure 4
Annual Hours Worked Over Time



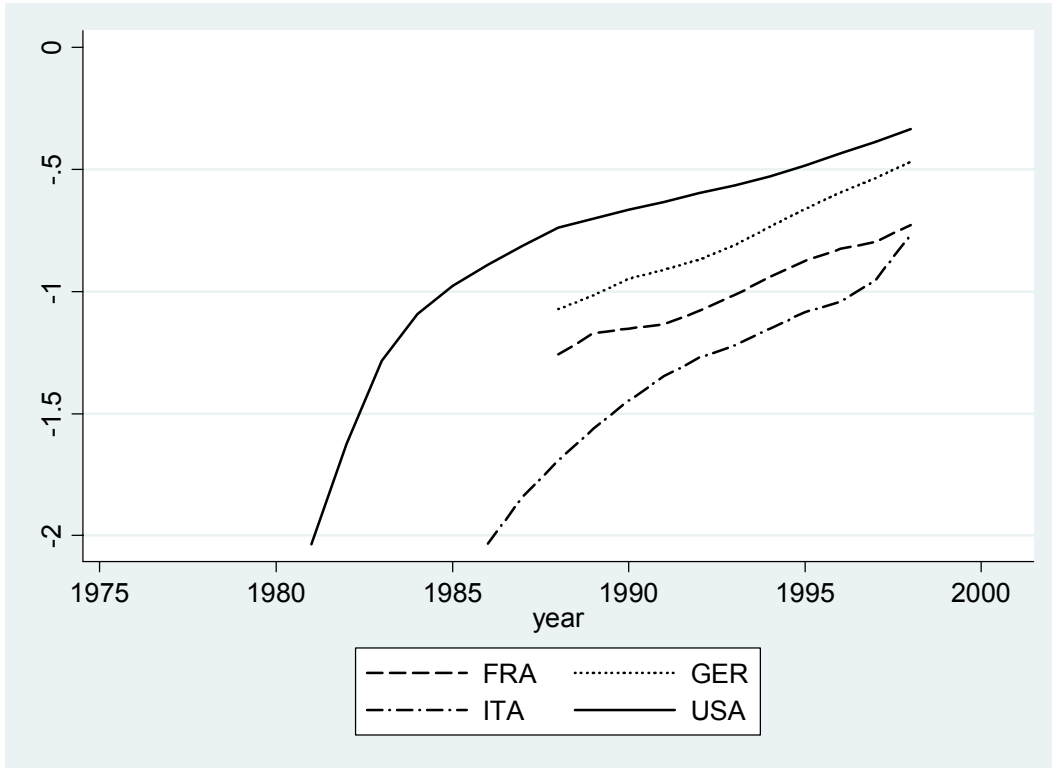
Source: OECD data. Annual hours per employed person. Annual hours are equivalent to 52*usual weekly hours minus holidays, vacations, sick leave. Reproduced from Alesina Glaeser and Sacerdote (2005)

Figure 5
Labor/Capital Ratio in “Continental” and “Anglo-Saxon” Countries
 (Index, 1972=1)



Source: Own calculations, based on data from the OECD Economic Outlook, December 2005. The computation is based on Blanchard (1997, p. 96), following the codes that he kindly provided, and the sample of countries is essentially the same as in that paper. However, some differences are worth mentioning: 1- Updated data set; 2- Australia is excluded, due to lack of data necessary to compute the GDP of the business sector; 3- We start in 1972, so that the sample of countries is exactly the same in every year (some countries have missing data before that year); 4- Cross-country averages weight countries in proportion to 2000 GDP in PPP units. Anglo Saxon countries are: US Canada and UK; Continental are Austria, Belgium, Denmark, France, West Germany, Ireland, Italy, Netherlands, Spain, and Sweden.

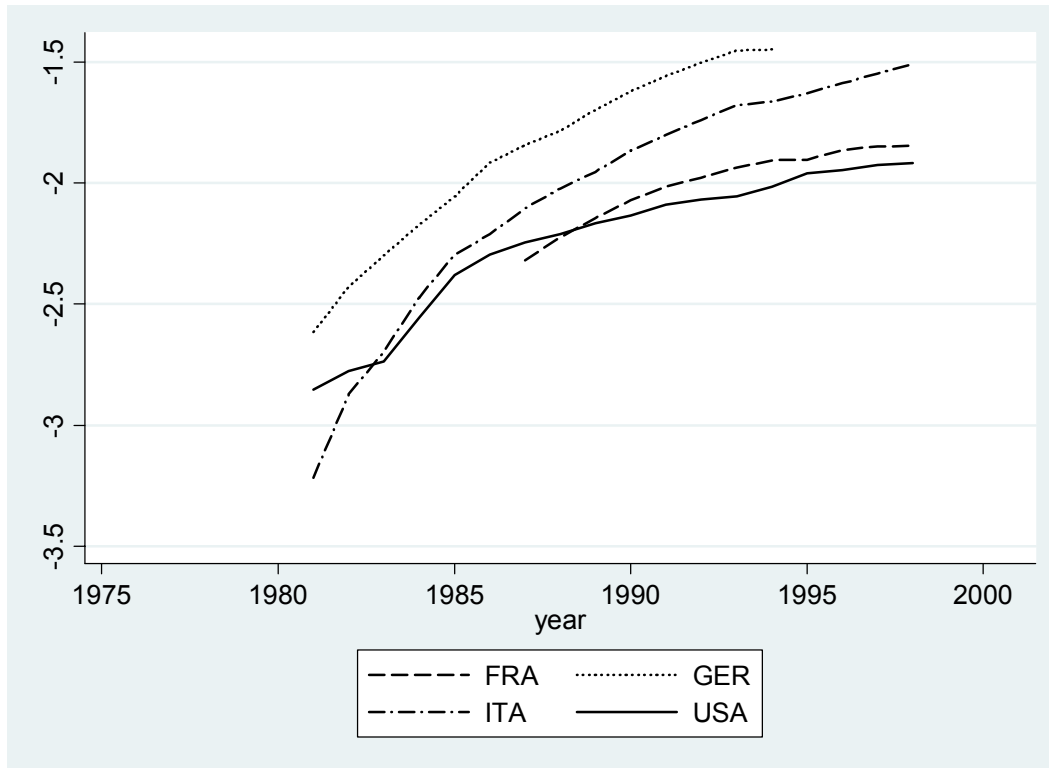
Figure 6
Personal Computers per capita
(in logs)



Source: HCCTA.

Figure 7

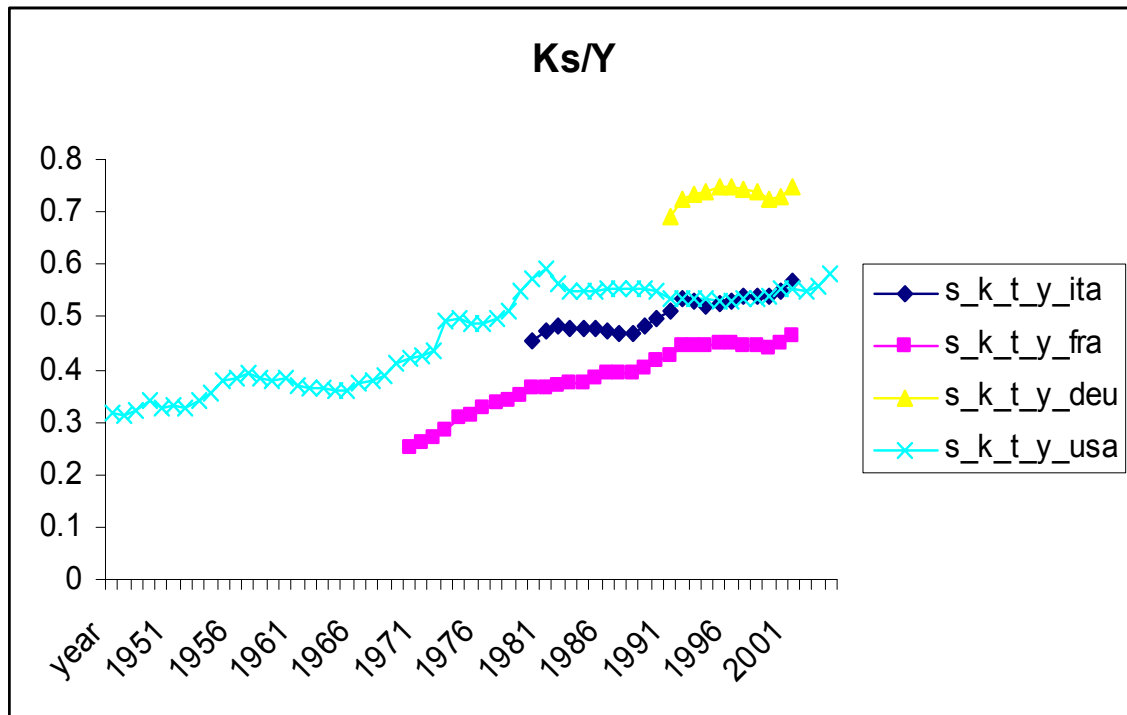
**Industrial Robots as share of GDP
(in logs)**



Source: HCCTA.

Figure 8

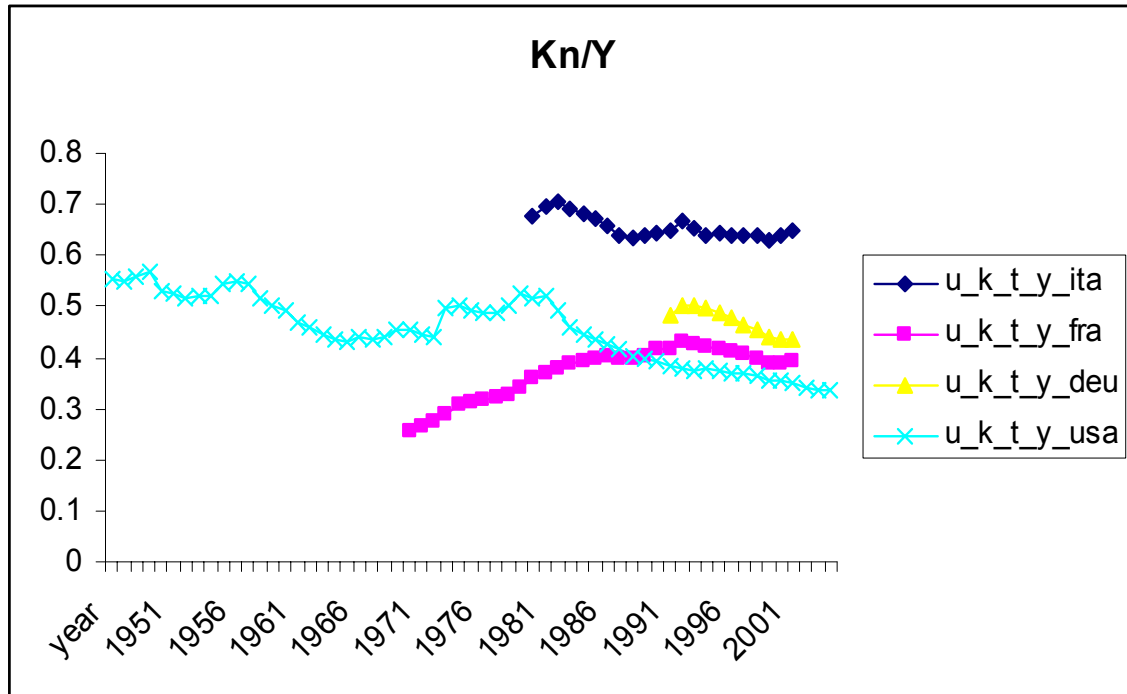
Ratio of Capital in Skilled Sectors to Output in US, France, Italy, and Germany



Source: OECD for France, Italy and Germany, BEA for the US.

Figure 9

Ratios of Capital in Low Skilled Sectors to Output in US, France, Italy and Germany



Source: OECD for France, Italy and Germany and BEA for the US.

Table 1
50-10 and 90-50 Weekly Earnings Ratios, Full-Time Workers

Country	50-10				90-50			
	1979-1981	1989-1990	1994-1998	% Change	1979-1981	1989-1990	1994-1998	% Change
A. Men								
United States	1.95	2.14	2.21	13.00	1.82	2.05	2.13	16.70
France (net earnings)	1.66	1.63	1.60	-3.90	2.04	2.14	2.06	0.80
Germany (West)	1.52	1.45	1.46	-4.30	1.68	1.71	1.80	7.20
Europe*								
Current sample	1.54	1.51	1.60	4.07	1.70	1.73	1.85	9.11
1979-1981 sample	1.54	1.56	1.57	1.95	1.70	1.77	1.82	6.82
B. Women								
United States	1.65	1.87	1.96	18.60	1.76	2.01	2.13	20.80
France (net earnings)	1.59	1.65	1.56	-2.00	1.70	1.71	1.71	0.40
Germany (West)	1.79	1.75	1.60	-10.60	1.73	1.59	1.64	-5.20
Europe*								
Current sample	1.58	1.57	1.62	3.07	1.60	1.62	1.71	6.85
1979-1981 sample	1.58	1.60	1.59	0.63	1.60	1.66	1.63	2.00

* Europe is defined as:

1979-81 - Austria, Finland, France, Germany, Sweden, United Kingdom.

1989-90 - Same as 1979-81, plus Belgium, Italy, Netherlands, Switzerland.

1994-98 - Same as 1989-90, plus Ireland, Spain. (In 1994-98, Austria and Belgium have data for the 50-10 ratio only.)