Technology and Labor Regulations[1]

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First draft: June 2006

Revised: September 2006

[1] We thank Olivier Blanchard and Larry Katz for useful suggestions and Filipe Campante for excellent research assistantship.

Abstract

Many 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. This paper suggests that the main difference between Europe and the US in this respect is their different labor market policies. 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 technical progress 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 bag 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 proposes a model which answers this question. It suggests that the main difference between Europe and the US that leads to such technological differences is their different labor market policies. European countries reduce wage flexibility and wage inequality through a host of labor market regulations, like binding minimum wage laws, permanent unemployment subsidies, firing costs, etc. These policies create incentives to develop and 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 of modeling differential technology adoption across countries. One is to assume that technology adoption is costly, like Parente and Prescott (1995). This approach helps 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 (1987) and 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 these models build strongly on externalities or returns to scale and thus apply mainly to very poor and rich countries, where factor endowments differ significantly, rather than differences between Europe and the US. We therefore use a third approach, following Zeira (1998) and Champernowne (1963), which models technological progress as substituting labor by machines. According to this approach technological innovations reduce the input of labor but require purchasing machines, namely increasing capital input. Hence, such technological innovations are adopted only if wages are sufficiently high, so that adoption reduces the overall cost of production.

In this paper we consider a model of two sectors, skilled and unskilled, and we show that the wage in each sector determines the degree of technical progress in that sector. The model allows the US and Europe to differ both in basic productivity and in labor market policy.[2] It then shows that a difference in basic productivity leads to one country being more advanced technologically than the other for all skill levels. This does not seem to be the case, as Europe seems to be more capital intensive at the low end of the skill spectrum. We therefore conclude that only different labor market policies can account for the above differences in technical progress between Europe and the US.

The different labor market policies followed by US and Europe have already been the focus of much economic research, especially since the two areas started to diverge in performance since the nineteen seventies, which were years of turmoil and high unemployment in both. Since then unemployment in Europe has shown a tendency to remain high, while unemployment in the US has declined steadily. This difference was

[2] By basic productivity we mean underlying productivity, like climate, proximity to sea, infrastructure, etc. It is different from measured productivity due to labor market policies and endogenous technical progress.

attributed by many economists to different labor market policies.[3] Unemployment has been just part of the story. The number of work hours per person has steadily declined in Europe (especially France, Germany and Italy) since the mid seventies relative to the US.[4] 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.[5] Our model is consistent with this.

Many economists have attributed the large rise in the wage skill differential in the US to skill biased technical change.[6] This paper implies 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.

In summary, the decline in labor unions' power and the reduction in labor market regulation in the US have been one of the causes of lower unemployment, higher wage

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[3] 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.

[4] This decline has been in part lower participation in the labor force, in part longer vacations, and in part shorter work weeks.

[5] 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.

[6] 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).

inequality and more skill biased technical change, while opposite policies in Europe led to higher unemployment, lower wage inequality, and more technical progress at low skilled sectors. Note that even though labor market regulations distort technological adoption and employment, they may not be sub-optimal (at least some of them) in an ex ante sense, for insurance (of the workers) purposes. This result, which in general is of course not new, holds even in our model, in which labor regulation distorts technological adoption. Interestingly, a simulation analysis we conduct, which builds on actual skill supplies in Europe and the US, points at a possibility that the US has a lower than optimal degree of unemployment compensations, while in Europe they are higher than optimal. This is raising the possibility that there is a significant difference in social preferences across the Atlantic, as emphasized by Alesina and Glaeser (2004).

The paper stresses the idea that a high cost of labor may lead to labor saving technologies. Some elements of this idea 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 difference. 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 of distribution amongst factors. Lewis (2005) discusses the low skilled versus high skilled relative supply in the US context but does not explore the role of labor market regulation and focuses on relative supplies of the two type of labor.[7]

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[7] Some recent papers focus on long-run growth aspects of the same idea. See Zeira (2006), Zuleta (2006) and others.

The paper is organized as follows. Section 2 presents the basic model. Section 3 discusses a variety of extensions in different directions. Section 4 relates the empirical implications of the model to what we know about developments in labor markets, unemployment and technology. The last section concludes and the appendix contains mathematical derivations of some results.

2. The Basic Model

2.1 The set up

The population in this economy lives in overlapping generations. The size of each generation is normalized to be 1. Each individual is born to a single parent, lives two periods and has a single offspring. Individuals work in first period of life only. An individual can work as skilled if studies, or as unskilled if does not study. For simplicity assume that 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. 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, which is random, distributed uniformly between zero and 1, and is independent of whether the individual is skilled or unskilled.[8] People derive utility from consumption in the two periods of life:

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

where $\rho > 0$.

[8] This assumption can be relaxed to get mobility between skilled and unskilled. The main results are not altered.

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

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

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

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

Each i can be produced by one of two potential technologies. One is an old manual technology, where a unit of i is produced by 1 efficiency unit of skilled labor. The second is an industrial technology that produces i by a machine. This machine is 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 and innovation is costless, so if there is demand for a machine it is invented. Hence, the only cost of the industrial technology is the cost of machines. It is assumed that this cost $k(i)$ is rising with i.[9] To solve the model analytically we use the following specification:

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

The unskilled good is produced by a similar production function:

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

[9] This is just an ordering assumption and has no effect on the analysis.

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), namely the two sectors are symmetric.

The economy is open to capital mobility and small, so that the world interest rate is given and equal to r. We denote the gross interest rate by $R = 1 + r$. To simplify things assume that the economy trades only in the final good, and not in skilled, unskilled and intermediate goods.

We 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.[10] Finally assume that there is an unemployment compensation, or a more general social insurance system, and if someone is out of job, she is entitled to v times the wage of unskilled, where $v < 1$ and it measures the degree of labor market regulation. In the next section we discuss other forms of labor market regulation. The transfer payments are financed by a tax on income, at a fixed rate t, which keeps the budget balanced. To keep the algebra simple assume that the tax is paid on the transfer payments as well.

2.2 Technology Adoption

We begin with a derivation of technical progress in the two sectors of the economy. Denote by w_n the gross wage rate per efficiency unit of an unskilled worker and by w_s the gross wage rate of an efficiency unit of a skilled worker. First, a skilled intermediate good is industrialized and produced by machines, if the cost of a machine is lower than that of labor, namely if:

[10] This assumption is made only to warrant that skilled wages are higher or equal than unskilled wages.

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

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

In a similar way the unskilled intermediate goods $i \leq f_n$ are produced by machines, where the technology frontier for unskilled is:

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

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.

We next turn to determine prices and wages. 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, prices of the intermediate goods in the skilled sector are:

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

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

The ε serves as notation for the term $\alpha \log \alpha + (1-\alpha)\log(1-\alpha)$. We call equation (9) the "goods markets equilibrium condition." Note that 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 strongly related to the degrees of technical progress in the two sectors:

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

Hence, we get the following relationship between the two technology frontiers:

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

We call it the "labor market constraint."

Together, the equations (9) and (10) determine the equilibrium values of technical progress and wages in each sector given the wage ratio between the two sectors. This is shown in Figure 1, which presents their intersection. The **G** curve describes the goods market equilibrium condition (9), while the **L** curve describes the labor market constraint (10). Note that due to our assumption that skilled workers can always switch and work as unskilled the wage ratio I satisfies: $1 \le I < \infty$.

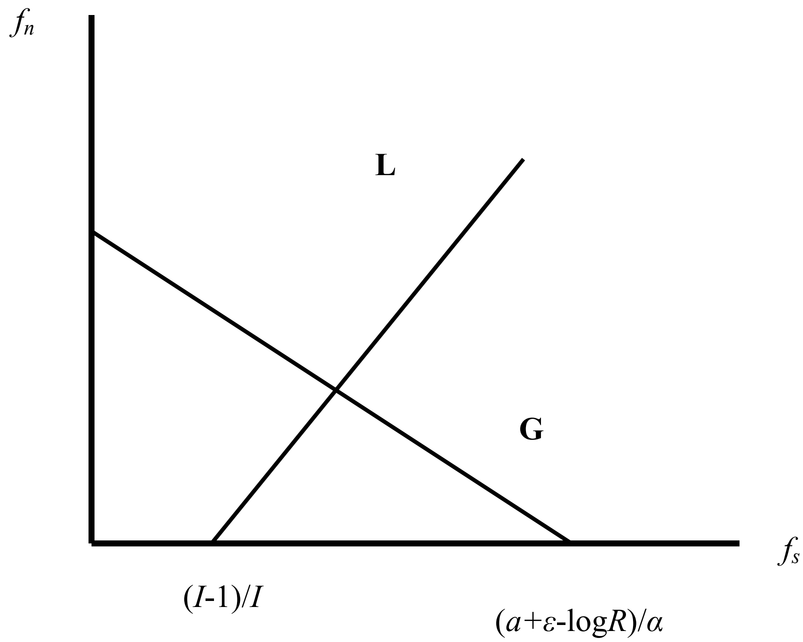

Figure 1: Determination of Technology Frontiers

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

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

and:

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

Note that the equilibrium is described by (11) and (12) only if there are no corner solutions. A sufficient condition that there is no corner solution at any wage inequality I between 1 and infinity is that the basic productivity a satisfies:

$$\alpha + \log R - \varepsilon \le a \le 1 + \log R - \varepsilon.$$

We next examine the effect of inequality I on technology. As wage inequality I increases, the curve **L** shifts down, reducing f_n and increasing f_s. This is clear from equations (11) and (12) as well. Hence wage inequality induces technical progress in the skilled sector but reduces technology adoption in the unskilled sector. As a result, the wage of skilled workers rises and the wage of unskilled workers declines.

Consider the effect of a change in productivity a. This shifts curve **G**. Hence, a country with higher productivity has higher technical progress in both sectors, skilled and unskilled. Hence, if this model applies, and if technical progress in Europe is higher than in the US in the unskilled sector and lower in the skilled sector, this cannot be a result of differences in basic productivity between the two regions, but only a result of differences in wage inequality I, or in labor market institutions. We return to this point below, where we find how wage inequality is determined.

2.3. Equilibrium Wage Inequality

We next discuss the two labor markets, for skilled and unskilled, in order to derive the wage ratio I and find the equilibrium. Workers care only about their net income, as is clear from the utility function (1). A skilled worker with efficiency e earns ew_s before tax, while an unskilled worker with efficiency e earns ew_n. A worker chooses to work only if her earnings exceed the welfare payment. Hence an unskilled decides to work only if:

$$ew_n(1-t) \geq vw_n(1-t).$$

As a result, the unskilled $[v, 1]$ work and their rate of unemployment is

(13) $$u_n = v.$$

A skilled supplies labor if:

$$ew_s(1-t) \geq vw_n(1-t).$$

Hence, the rate of unemployment among the skilled is

$$u_s = \frac{v}{I}. \tag{14}$$

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

$$\frac{L_s}{2}\left(1-\frac{v^2}{I^2}\right) = \frac{\alpha RY}{w_s^2}. \tag{15}$$

The equilibrium in the market for unskilled labor is reached at:

$$\frac{L_n}{2}\left(1-v^2\right) = \frac{(1-\alpha)RY}{w_n^2}. \tag{16}$$

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

$$I^2 = \frac{\alpha}{1-\alpha}\frac{L_n}{L_s}(1-v^2)+v^2. \tag{17}$$

We assume that $\alpha L_n /[L_s(1-\alpha)] \geq 1$ since it must hold anyway. Otherwise the supply of skilled is too large and the right hand side of (17) 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 the condition is restored. This assumption 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

Consider next the effect of an increase in v. A country with a larger unemployment compensation v has a lower wage inequality I. The reason is that it affects the unskilled workers by much more than the skilled ones. As a result this country has less technical progress in the skilled sector, namely f_s is lower, but has more technical progress in the unskilled sector, namely f_n is higher. As a result, in this country w_s is lower and w_n is higher. Another potential reason for a higher technical progress among unskilled and lower among skilled, can be a lower relative supply of unskilled labor, namely L_n/L_s. But since we know that skill is more abundant in the US than in Europe this cannot be the reason for lower wage inequality in Europe. Hence, the only explanation left for the differences in technical progress between US and Europe, according to this model, is different v, namely different labor market policies.

2.5. Output and Fiscal Policy

In this economy unemployment among unskilled is higher than among skilled. The aggregate unemployment rate is equal to:

$$u = L_n v + L_s \frac{v}{I} = v\left[1 - L_s\left(1 - \frac{1}{I}\right)\right]. \tag{18}$$

It can be shown that unemployment rises with v. The level of output in the economy can be calculated by use of equation (15):

$$Y = \frac{L_s}{2\alpha R}\left(1 - \frac{v^2}{I^2}\right) w_s^2. \tag{19}$$

It follows that labor market regulation v reduces output. An increase in v reduces I and reduces w_s. Hence output declines. The reason is the reduction in labor supply.

A balanced budget policy in this economy requires setting a tax rate that satisfies:

(20) $$tY = (L_n u_n + L_s u_s) v w_n = \left(L_n v + L_s v / I\right) v w_n.$$

Note that if v is higher I is lower and w_n is higher. Hence 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 (20) is higher. Since output or income is lower, the tax must be higher. This is of course not surprising, since larger transfer payments require higher taxes. Next we examine the combined effect of transfers and taxes on welfare.

2.6. Welfare Considerations

In this sub-section we examine the ex-ante expected utility of each person at birth, before her efficiency is known, as this is the correct measure of welfare. This is actually the average utility of skilled and unskilled in each generation. In the appendix we show that utility is a simple linear transformation the logarithm of net income, and since we are interested only in comparing utility we will use the expected logarithm of net income as a measure for expected utility from here on. The appendix shows that the expected ex-ante welfare of an unskilled worker is equal to:

(21) $$U_n = \log w_n + v + \log(1-t) - 1.$$

The expected ex-ante welfare of a skilled worker is equal to:

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

The effect of increasing v 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.

We next focus on the average welfare in a generation, which is the only welfare that matters, since the government does not transfer income across generations. Average ex-ante expected welfare, with equal weights to all, is equal to:

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

The calculation of average utility is quite complicated and we resort to use simulations. For that, we must specify reasonable values for the four basic parameters of the model: the productivity parameter a, the gross interest rate R, share of skilled labor in the production of the final good α, and share of skilled workers in the population L_s. Our choice parameters is guided by our main interest in comparing the US and Europe. It is plausible to assume that there is not much difference between US and Europe in interest rates and production parameters, so that our exercise centers on comparing equilibrium outcomes across different values of L_s, keeping the other parameters fixed.

To choose the values of L_s note that the percentage of the population between ages 15 and 64 that had completed tertiary education in 1995 was 33% in the US and 17% in Europe, where "Europe" is taken to be the average of France, Germany, and Italy.[11] Thus US is represented by $L_s = 0.33$, and Europe is represented by $L_s = 0.17$. As for the remaining parameters, $R = 2$ is a realistic interest rate for a period of one generation. To set α note that the ratio of wages of college graduates and high school graduates in the US has been in the late 1990s equal to 1.9, as shown by Autor, Katz, and Kearney (2005). Hence, α must be higher than .64 according to equation (17),even for

[11] See Barro and Lee (2001).

low v. We therefore set $\alpha = 2/3$. Finally, the productivity parameter a is set to satisfy the above condition for an interior solution $\alpha + \log R - \varepsilon \leq a \leq 1 + \log R - \varepsilon$. This implies $1.99 \leq a \leq 2.33$, so we set $a = \log(8) \sim 2.08$.

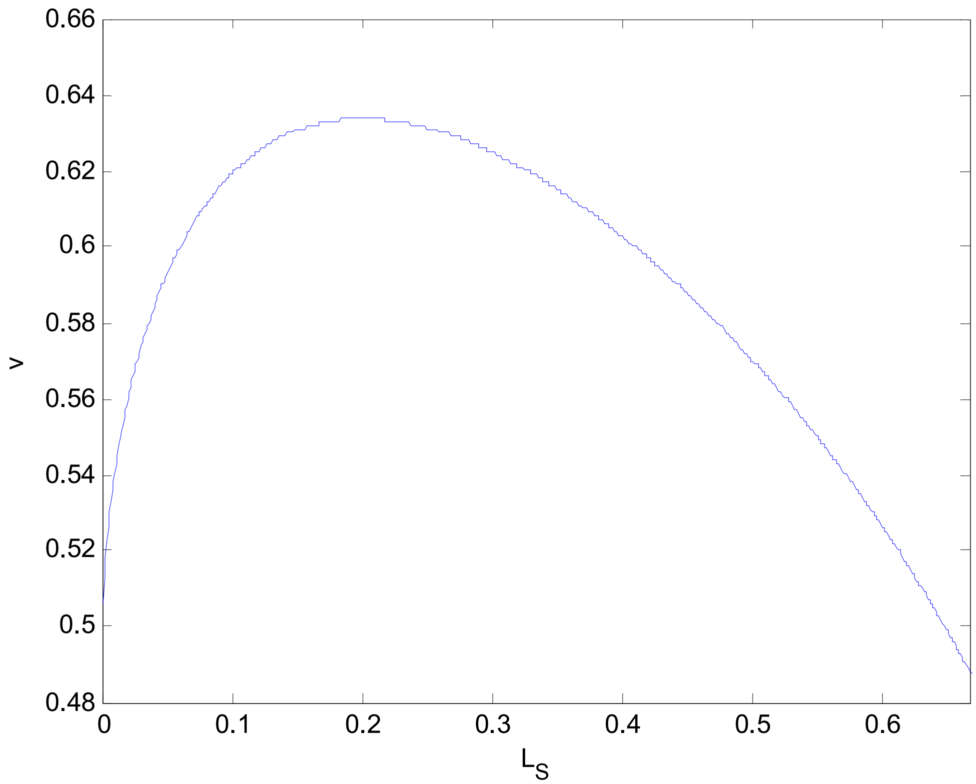

Figure 2: Optimal Unemployment Compensation

Figure 2 shows how optimal v, which maximizes AVG (U), changes with the amount of skill. Note that Figure 2 is drawn for $L_s \leq 2/3$, since this is implied by constraint $\alpha L_n / (1-\alpha) L_s \geq 1$, which is required by $I \geq 1$. The relationship in Figure 2 is not monotonic, but it is clear though that for any amount of skill the optimal value of v is positive. Hence, labor market regulation increases welfare by supplying insurance against being born with low efficiency.[12]

The locations of the US and of Europe along the curve in Figure 2 tell us what are their optimal unemployment compensation. We can use equation (17) to calculate their actual v, namely their actual unemployment compensation, according to our model. Then we compare the optimal with the actual. The optimal v for the US should be .619. Its actual v that fits the US wage ratio of 1.9 is .383. The optimal v for Europe should be .633. But the wage ratio in Europe is 1.4 according to Brunello, Comi, and Lucifora (2000), and that fits v = .943. We therefore conclude that according to this simulation unemployment compensation in the US is significantly below the optimal, while in Europe it is significantly above the optimal. This shows that 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 choices made on the two sides of the Atlantic.

3. Extensions

3.1 Minimum wage laws

This sub-section shows that a binding minimum wage floor can have a very similar effect as the unemployment compensation we examine in the benchmark case. 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 to the

[12] Note here that we can consider a Pareto-dominating policy, of means tested transfer payment. But it is reasonable to assume that such a policy is impossible if efficiency is known to workers but not observed if the worker does not work. Then workers with low efficiency prefer avoid work altogether. Under such moral hazard the policy in the model is indeed optimal.

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.[13] We also assume that unskilled firms are sufficiently large so that the distribution of workers' efficiency within each firm is the same as the aggregate distribution. Clearly, despite the different levels of efficiency in the unskilled sector, workers are paid the same wage w_n due to asymmetry in information. Finally, we assume that there is minimum wage regulation that sets the wage of unskilled to be at some ratio with the skilled wage:

$$w_n = gw_s. \tag{23}$$

The parameter g measures the degree of labor market regulation in this case. We do not explicitly model a system of unemployment compensation, but adding it will leave the results unchanged as long as the compensation is lower than the wage rate.

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:

$$E_n(i) = \frac{w_n}{p_n(i)}.$$

The unskilled workers who are left in production are therefore those who have higher efficiency or those who have not been monitored.

[13] The assumption of partial monitoring is added here because otherwise no one gains from the minimum wage, as shown below, so it cannot be justified.

Next consider technology adoption. In the skilled sector technology adoption 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:

$$\frac{R}{1-f_s} = w_s. \tag{24}$$

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. As shown in the appendix the technology frontier in the unskilled sector is described by:

$$\frac{R}{1-f_n} = xw_n, \tag{25}$$

where x is determined by m in the following way:

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

In a similar way to the benchmark model we can now derive the demands for the intermediate goods, equate them with the supply prices and get the same "goods market equilibrium condition" (9), as in Section 2. Given that the ratio between the unskilled and skilled wages is g due to wage compression (23) and conditions (24) and (25) we get:

$$f_s = 1 - gx(1-f_n). \tag{26}$$

Together (9) and (26) determine technology adoption and wages. Clearly a rise 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.

As for unemployment, if g is higher than the equilibrium wage ratio, there are two types of unemployed unskilled. There are $mE_n = m/x$ fired workers, and there are workers who are not hired at all, since the unskilled wage rate is too high. It can be shown that 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 set at a higher level than I_e there will be unemployment due to a lower demand for unskilled. A welfare analysis similar to the one in Section 2 can show that despite the negative effects of minimum wages on some, it raises income for others and as a result the optimal degree of such regulation is not necessarily zero.[14]

3.2 Firing Costs

This extension examines another type of labor market regulation, firing costs. Assume that the model is similar to the benchmark model except for one difference. Individual efficiency e is not observed by the worker but only by the employer, as it is observed on the job. We further assume that an employer can fire a worker, but this act is costly. The firing costs are h in terms of the final good. We also assume that firms are sufficiently large so that the distribution of workers' efficiency within each firm is the same as the aggregate distribution. Again, we do not explicitly add a system of unemployment compensation, but adding it will leave the model unchanged as long as the compensation is lower than the wage rate.

In order to derive the equilibrium we begin with an employer who uses skilled labor to produce an intermediate good. The employer pays all workers the same wage, irrespective of efficiency, due to asymmetric information. But as the employer knows the efficiency of workers, he will fire those with efficiency e that satisfies:

$$ep_s(i)-w_s<-h.$$

[14] Such a welfare analysis requires adding to the model some system of unemployment payments, since utility is logarithmic.

Hence, the threshold for firing skilled workers $E_s(i)$ is determined by:

(27) $$E_s(i) = \frac{w_s - h}{p_s(i)}.$$

The firing threshold in the unskilled sector is similar.

It follows from (27) 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 (27) we get:

(28) $$p_s(i) = p_s = w_s + \sqrt{h(2w_s - h)},$$

and:

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

Hence, increasing the firing costs raises the price, obviously, and reduces E, namely they deter firing. 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:

(30) $$\frac{R}{1 - f_s} = p_s.$$

The technological threshold in the unskilled sector is similar.

In a similar way to the benchmark model we can now derive the demands for the intermediate goods, equate them with the supply prices and get the same “goods market equilibrium condition” as condition (9) in the benchmark model.

To complete the analysis we get the equilibrium conditions in the two labor markets by equating supply and demand in efficiency units. In the Skilled sector we get:

$$\text{(31)} \qquad \frac{\alpha Y}{L_s} = \frac{\sqrt{\frac{2Rh}{1-f_s}} - h}{1-f_s}.$$

The equilibrium condition in the market for unskilled labor is similar. From the two equilibrium conditions we derive the following labor market equilibrium condition:

$$\text{(32)} \qquad \frac{\sqrt{\frac{2Rh}{1-f_s}} - h}{1-f_s} = \frac{\alpha}{1-\alpha}\frac{L_n}{L_s}\frac{\sqrt{\frac{2Rh}{1-f_n}} - h}{1-f_n}.$$

This labor market equilibrium condition is a positive relationship between f_n and f_s. Hence, together with the “goods market equilibrium condition” it determines a unique general equilibrium. We can also use a diagram similar to Figure 1 to analyze it. For example we can now examine the effect of changes in firing costs and show that a rise in firing costs h increases f_n and lowers f_s. Namely, more machines are used in the unskilled sector and less machines in the skilled sector.

3.3 Aversion to Inequality

Thus far we have shown how various labor market regulations indirectly determine a level of wage inequality I lower than the unconstrained labor market would generate. Often limiting wage inequality is a direct objective of labor unions and governments, especially in Europe.[15] More precisely unions (and governments) are willing to incur the efficiency costs of adopting policies explicitly targeted to limit wage inequality. A very simple way to capture this would be to impose a constraint on *I*. [16] While we do not develop this extension further the intuition is clear: in our previous analysis, the effects of various forms of regulation affected the equilibrium by means of distorting the free-market determination of *I*. Obviously one can get the same qualitative results by imposing an exogenous upper bound on wage inequality.

4. Discussion of empirical implications

In this Section we describe many facts and empirical results that support various elements of the story we tell in our model. We divide the empirical evidence to three main areas: evidence on differences in labor market regulation between Europe and the US, evidence on differences in wage inequality, and evidence on differences in technology adoption in different ranges of the skill distribution.

4.1. 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.

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

[16] More generally one could extend the model to a case in which wage policy is set by a monopoly union which is willing to incur the costs of unemployment (especially in the unemployed are not union members) in order to obtain less inequality for those who work.

What happened? As for unemployment, a fairly accepted view goes as follows. The supply shocks of the seventies were accompanied by wage moderation in 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.[17] As convincingly shown by Blanchard and Wolfers (2000), the interaction of this kind of labor institutions and those macroeconomic shocks generated persistent unemployment.[18]

Lets' now turn to the decline in work hours per person in Europe, a topic that has recently attracted much attention, given its remarkable magnitude. Alesina, Glaeser and Sacerdote (2005) argue that the most important explanation for this decline 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.[19] Regulations about required holiday, overtime, lower work week hours, have done the rest. European unions argued that work sharing with the same wage (thus increasing real wage per hour) was a way of redistributing a fixed amount of work hours amongst more people.

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

[18] Subsequent work by Bertola Blau and Kahn (2002) confirms these results.

[19] 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)).

4.2. 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. In these years the US experienced a significant increase in the wage gap between skilled and unskilled.[20] The wage dispersion in the US became much higher than in Europe. 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 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. For men in the 1994-1998 period for instance the ratio 50 to 10 is 2.21 in the US versus 1.6 in Europe while in the same years the 90-50 ratio is 2.13 in the US and 1.85 in Europe (2.06 in France). At the beginning of the period this difference is even more pronounced. Note that union policies are more likely to affect wage dispersion in the bottom half rather than in the top half of the wage distribution, and 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.[21]

Actually, stronger unions in Europe not only reduced the wage gap in Europe, at the time that it increased in the US, they even managed to maintain a relatively steady

[20] See Katz and Murphy (1992) for early work on relative supply of skilled versus unskilled labor.
[21] See also Gottschalk and Smeeding (1997) for a discussion of wage dispersion in OECD countries.

growth of real wages. Men's real wages declined in the US from 1979 till the end of the century, while wages increased substantially in Europe. Women's salaries increased in the US but less than in Europe.[22]

4.3. Differences in Technology

The labor market developments have been accompanied by an increase in the capital labor ratio in Europe. As already pointed out by Blanchard (1997), 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 the capital labor ratios are steadily and sharply increasing in Continental economies, while they have been quite stable in the Anglo-Saxon economies, as we also show 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 are not aware of any systematic study on whether technical progress and the increase in the capital-labor ratio in Europe have indeed displaced low skilled workers relative to high skilled workers. We have assembled though some casual evidence that is consistent with the hypothesis that capital has substituted for low skill work. We first present some data assembled by Comin and Hobijn (2004). Their data set contains information on adoption of some technologies by 24 countries from the last 215 years. We compare US to France Germany and Italy, three of the largest Continental European countries with highly regulated labor markets. For many of the technologies in the data

[22] See Blau and Kahn (2002).

set it is unclear whether they are low skill or high skill labor saving, but for two cases we feel pretty confident. 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 for relatively 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 other three European countries while there are significantly more robots per capita the three European countries than in the US.

Another technology that presents a sharp difference in adoption between Europe and the US is railway electrification. Clearly, there are many factors that affect the decision to electrify railways, like density of transportation, but one is also wages, since electrified railways are capital intensive, while diesel locomotives require more labor, and mainly more unskilled labor. Interestingly, the US had more electrified rails in the past, 3,000 thousand route miles in the 1930s, while now it went down to less than 1,000 route miles. Less than a percent of US railways are electrified, and only 47 locomotives out of more than 20 thousand are electric. In France, Italy and Germany on the contrary 45% of the locomotives are electric, and the percentage of electrified rail is even higher.[23]

An additional interesting and suggestive evidence to our model, which builds on data within the US, is Lewis (2005). Using plant level data, Lewis 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. This suggests that availability and relative costs of low skill workers affect firms' technological choices. The same author even finds evidence of de-adoption of automation technologies in cities that receive an especially large influx of immigrants.

[23] See World Bank Railways Database (2006).

4.4. Public employment

It is important to note that the extent of unemployment in European countries would have been even greater without the use of public employment to alleviate unemployment at relatively low skilled level. Evidence on this point is 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 Italy. Our model can easily account for this by redefining the unemployment subsidy as the wage of a public job. Then a worker would accept a job in the private sector only at a wage higher than the public sector job. The "unemployed" in our model would then be redefined as public employees. Another relevant factor is that when low skilled jobs are scarce, the opportunity costs of staying in school declines and young people stay in school longer. In Italy the average age of college graduation is 27.8.[24]

5. **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 some elements were even further deregulated. The US experienced a sharp increase in wage inequality, a stagnation of real wages for low skilled work, low unemployment and stability of labor force utilization in terms of hours per person in working age. 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

[24] See Dornbusch, Gentilini and Giavazzi (2000) on this issue.

laws and similar regulations. These policies fit with the general European aversion to excessive inequality. 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 affected technical progress and led to differences between the two regions. We show that 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. Our model therefore looks at the patterns of technical progress and their skill bias not only as endogenous, but also as affected by labor market policies and by wage gaps in various regions.

In summary our model suggests that the nature of technical progress is influenced by wages and by labor market policies. 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. More empirical work is needed to assess more directly the effects suggested by the paper. As for welfare, while we show that some insurance to labor outcomes raises welfare, one should investigate more thoroughly the comparative role of different types of welfare and labor protection laws.

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Appendix

Derivation of the Goods Market Equilibrium Condition

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

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

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:

$$\log S = a + \int_0^1 \log \frac{P_S S}{p_s(i)} di = a + \log S + \log P_S - \int_0^{f_s} \log \frac{R}{1-i} di - \int_{f_s}^1 \log w_s di =$$

$$= a + \log S + \log P_S - f_s \log R - (1-f_s)\log w_s + \int_0^{f_s} \log(1-i) di.$$

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) $$\log P_S = f_s + \log R - a.$$

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

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

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

$$P_S = \frac{\partial Y}{\partial S} = \alpha S^{\alpha-1} N^{1-\alpha} = \frac{\alpha Y}{S},$$

and:

$$P_N = \frac{\partial Y}{\partial N} = (1-\alpha) S^{\alpha} N^{\alpha} = \frac{(1-\alpha)Y}{N}.$$

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

(A4) $$\alpha \log P_S + (1-\alpha)\log P_N = \varepsilon,$$

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.

<u>Derivation of the Labor Market Equilibrium Conditions</u>

The supply of skilled labor in efficiency units by those who work is equal according to (14) to:

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

The supply of unskilled labor is equal according to (13) to:

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

The demand for skilled labor is equal to:

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

The demand for unskilled labor is equal to:

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

Equating the supplies and demands yields the equilibrium conditions (15) and (16).

<u>Derivation of Expected Utilities</u>

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. We therefore treat log$j$ as utility from here on. Expected utility of a skilled worker before efficiency is realized is:

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

This leads to equation (23). The ex-ante expected utility of skilled workers is calculated in a similar way.

<u>Derivation of Technology Frontier in the Unskilled Sector for Minimum Wage</u>

The technological frontier at the unskilled sector is determined at the point where the unit cost of machinery is equal to the average unit cost of producing by labor:

(A.5) $$\frac{R}{1-f_n}=\frac{m\int_{E_n(i)}^1 w_n de+(1-m)\int_0^1 w_n de}{m\int_{E_b(i)}^1 ede+(1-m)\int_0^1 ede}=2\frac{w_n-m\dfrac{w_n^2}{p_n(i)}}{1-m\dfrac{w_n^2}{p_n^2(i)}}.$$

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.5) that:

(A.6) $$p_n(i)=2\frac{w_n-m\dfrac{w_n^2}{p_n(i)}}{1-m\dfrac{w_n^2}{p_n^2(i)}}.$$

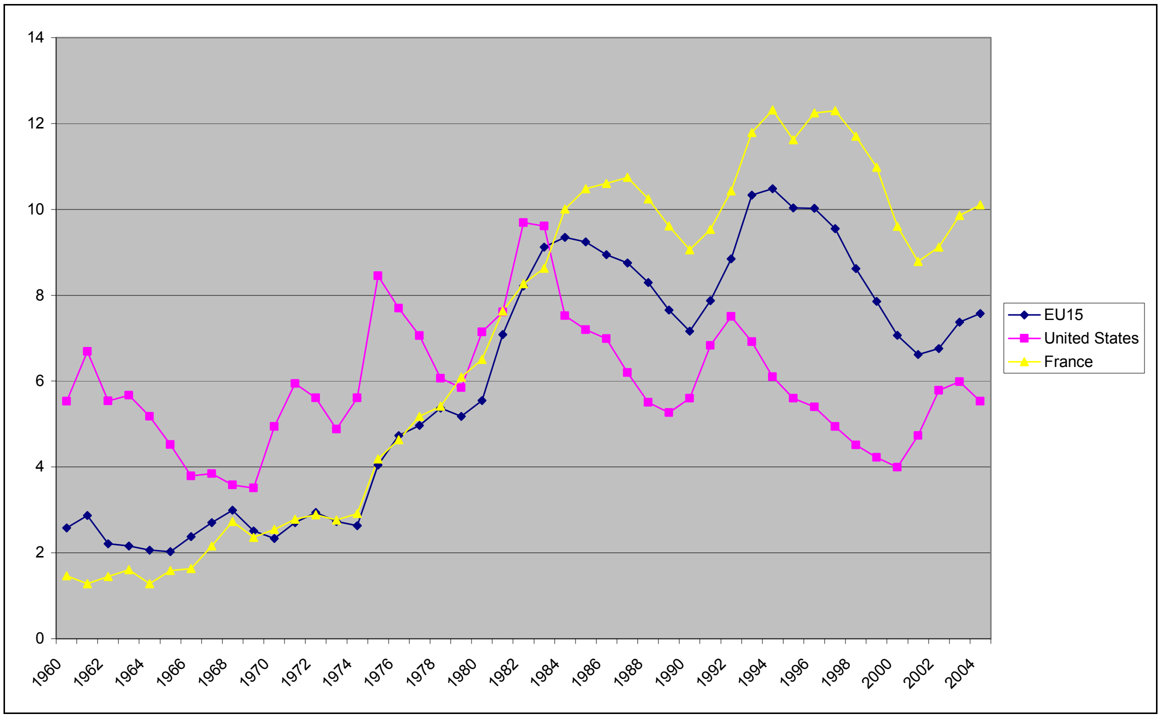
Solving (A.6) shows that the price is equal to: $p_n(i)=p_n=xw_n$ where x is:

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

This proves equation (25).

Figure 3

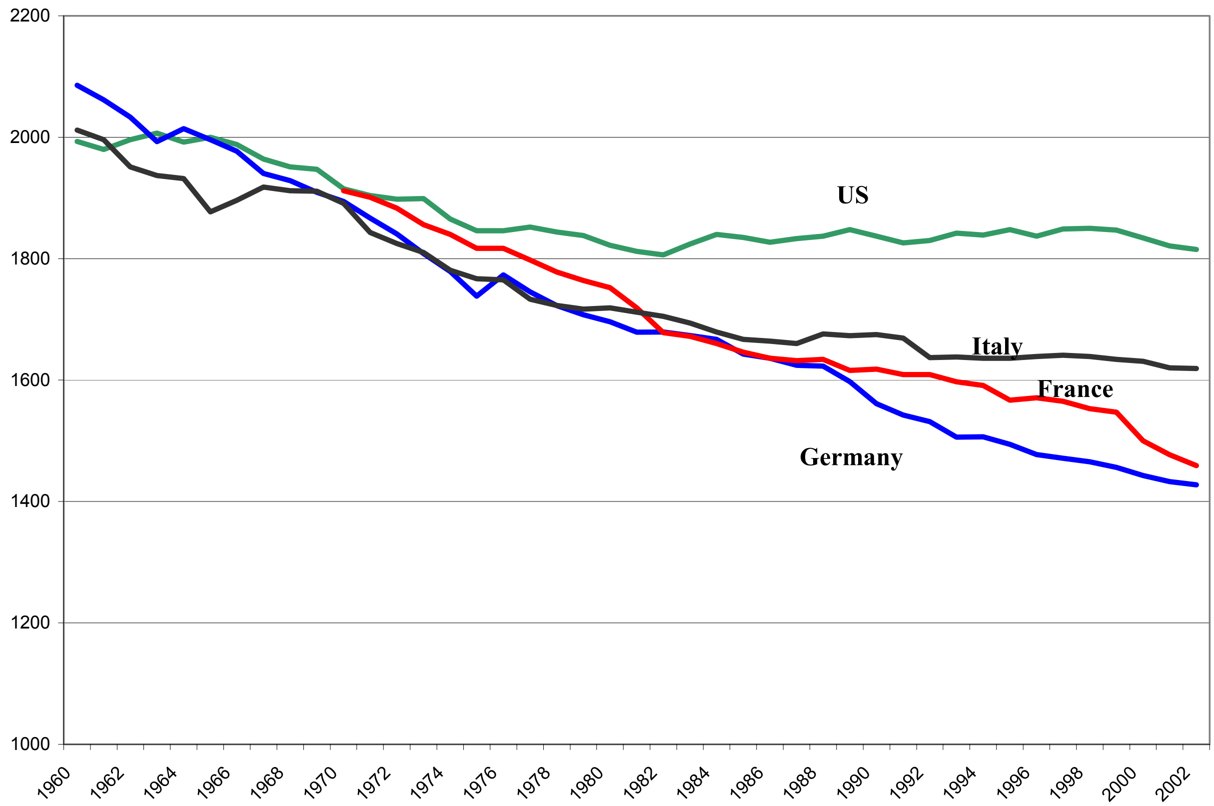
Unemployment Rate, 1960-2004 (%)



Source: OECD.

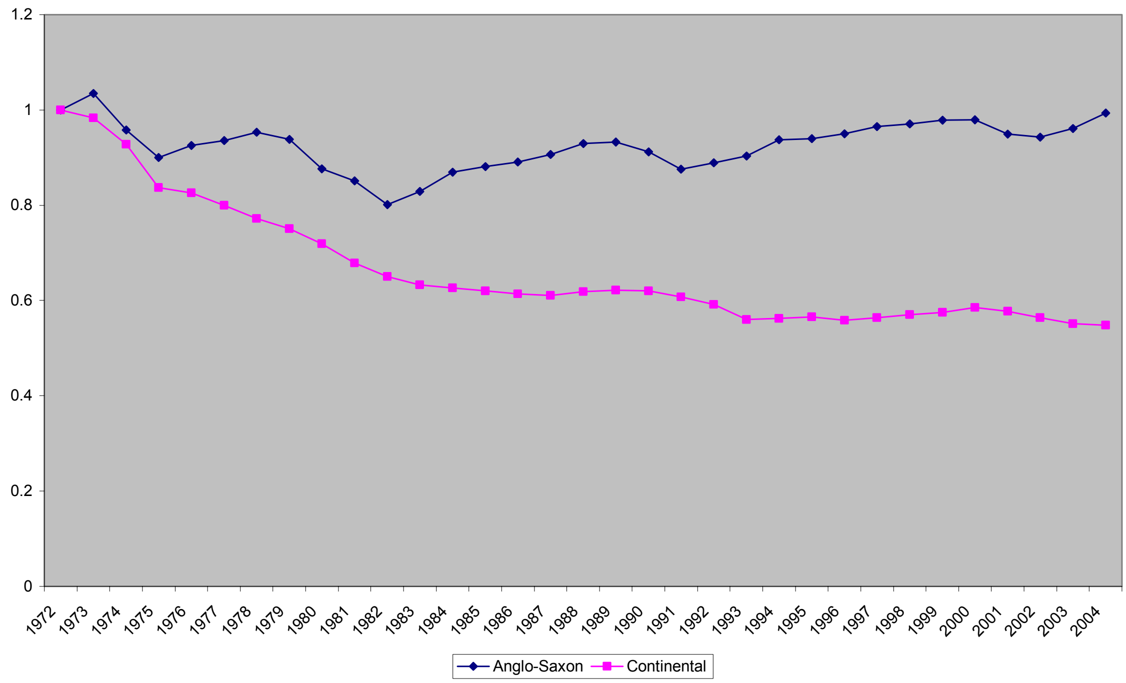
Note: EU15 corresponds to an unweighted average. Before 1977, not all countries from the EU15 are in the sample (as many as seven countries missing in some years); data from the Netherlands are available only until 2002.

Figure 4
Annual Hours Worked Over Time



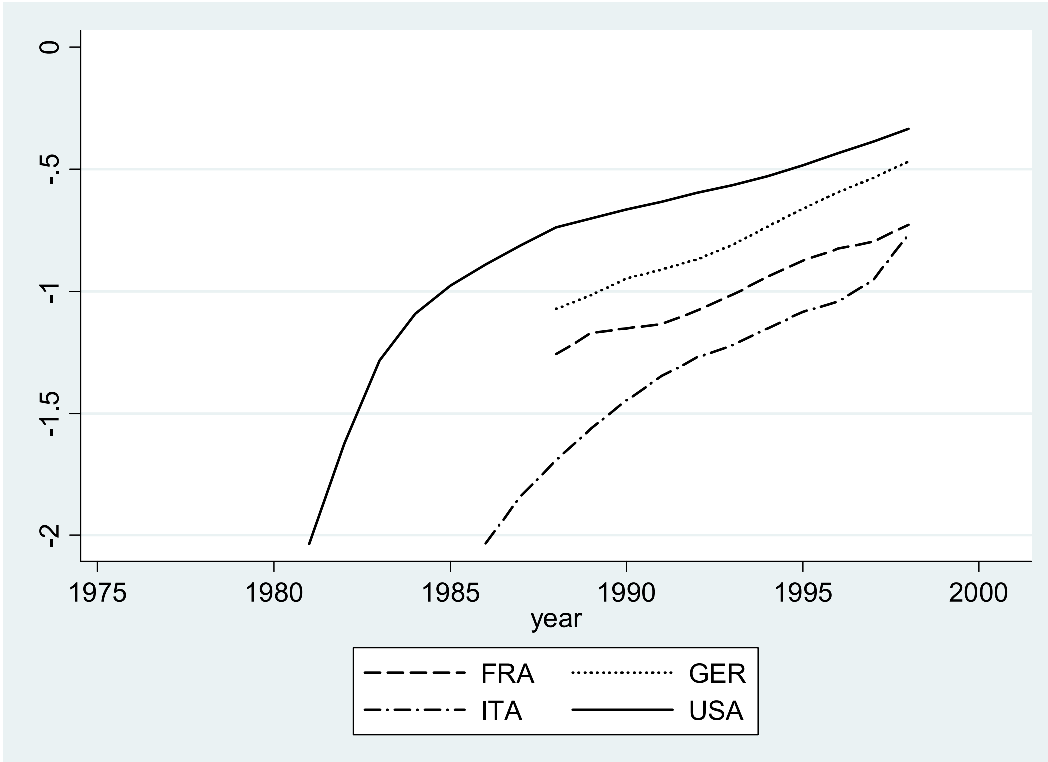
Source: OECD data. Annual hours per employed person. Annual hours are equivalent to 52*usual weekly hours minus holidays, vacations, sick leave. Reproduced from Alesina Glaeser and Sacerdote (2005)

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.

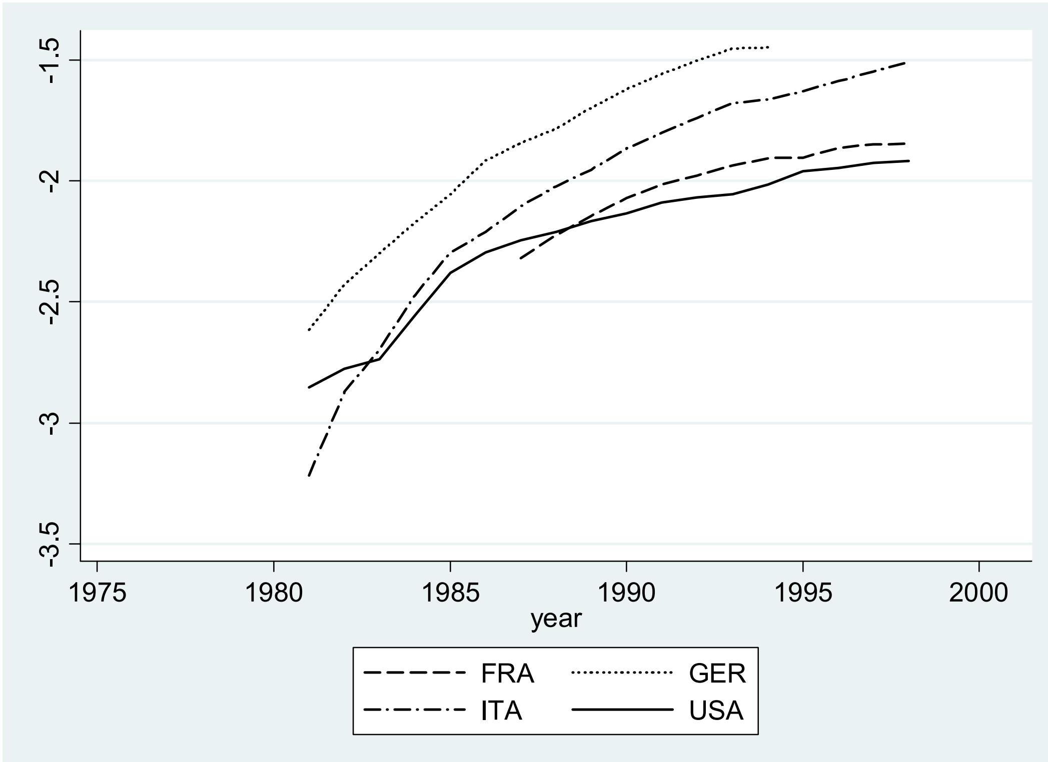
Figure 6
Personal Computers per capita
(in logs)



Source: HCCTA.

Figure 7

Industrial Robots as share of GDP
(in logs)



Source: HCCTA.

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

	50-10				90-50			
Country	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.)