The Effects of Labor Market Conditions on Working Time: the US-EU Experience*

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Abstract

Individuals often decide to work longer hours to increase future as well as current income. By working longer hours they acquire greater skills, and can obtain better jobs. In a market with search frictions, several features of the labor market can then influence the decision on working time. We show that a higher probability of becoming unemployed, a longer duration of unemployment, and in general a less tight labor market discourage working time. Wage inequality gives instead incentives to work longer hours. We argue that the different evolution of labor market conditions in the US and in Continental Europe over the last three decades can explain a substantial part of the diverging evolution of the number of hours worked per employee across the two sides of the Atlantic. It can also explain why the fraction of prime age male workers working very long hours has remained stable in Europe while it has increased substantially in the US.

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1 Introduction

In standard formulations of the competitive labor market model with separable utility, workers choose how many hours to work by equating the marginal utility of leisure to the marginal value of *current* income. The current market wage and the worker's wealth are the main determinants of the choice. In practice however individuals may decide to work longer hours in order to increase future as well as current income. By working longer hours they acquire greater skills, get promoted in the current job, and obtain better jobs. In this paper we analyze the determinants of the working time decision in a labor market subject to search frictions when hours worked are a means of accumulating human capital. We argue that individual working time decisions are intrinsically interrelated with several aggregate features of the labor market.

Our model is an extension of the standard search model of unemployment originally due to McCall (1970) where we allow for on-the-job search and a working hours decision. Hours worked increase current as well as future income. By working longer hours workers can acquire greater skills and increase their opportunities to obtain job offers. Thus hours worked have both an intra-temporal and inter-temporal return. Workers can become unemployed. If unemployed, they search for a new job. If employed, they can receive job offers from a given wage distribution.[1] Thus there is wage dispersion and identical workers can earn different income.

We show that a rise in wage inequality raises the gains from obtaining better jobs and gives workers greater incentives to work longer hours. In contrast, a higher probability of becoming unemployed and a longer duration of unemployment reduce the rate of use of the stock of human capital accumulated through working time and thereby reduce the incentive to work longer hours.

These considerations can help explain the different evolution of working time in the US and in Continental Europe in the post World-War-II period. Since the 70's, the number of hours worked per employee has fallen in Continental Europe (Germany, France, Italy) while it has remained roughly constant in the US. See for example OECD (2004, chap. 1) for some evidence. It is also well known that, since the 70's, the labor market has evolved quite differently across the two sides of the Atlantic. In particular:

1. The return to skill has increased substantially in the US while it has increased little

[1] Postulating an exogenous wage distribution has some key advantages given the question at hand. First, wage determination may differ substantially in Continental Europe and in the US. Second the wage distribution has evolved differently over time and there is yet no consensus of why this happened, see Hornstein, Krusell, and Violante (Forthcoming) for a survey on possible explanations. We sidestepped this debate by considering an exogenous wage offer distribution.

in Europe. See Eckstein and Nagypal (2004), Katz and Autor (1999) and Goldin and Katz (1999) for evidence specific to the US and Gottschalk and Smeeding (1997) for a cross-country comparison.

2. Within-skill wage inequality has increased dramatically in the US while it has remained roughly constant in Europe. See Juhn, Murphy, and Pierce (1993) for evidence specific to the US, and Flinn (2002) and Gosling and Meghir (2000) for evidence specific to Italy and the UK, respectively. See also Bertola and Ichino (1995) and Gottschalk and Smeeding (1997) for a cross-country comparison.

3. The unemployment rate has increased substantially in Europe while it has remained roughly constant in the US.[2] See Blanchard and Wolfers (2000) for a comparison of the evolution of unemployment in the US and Europe.

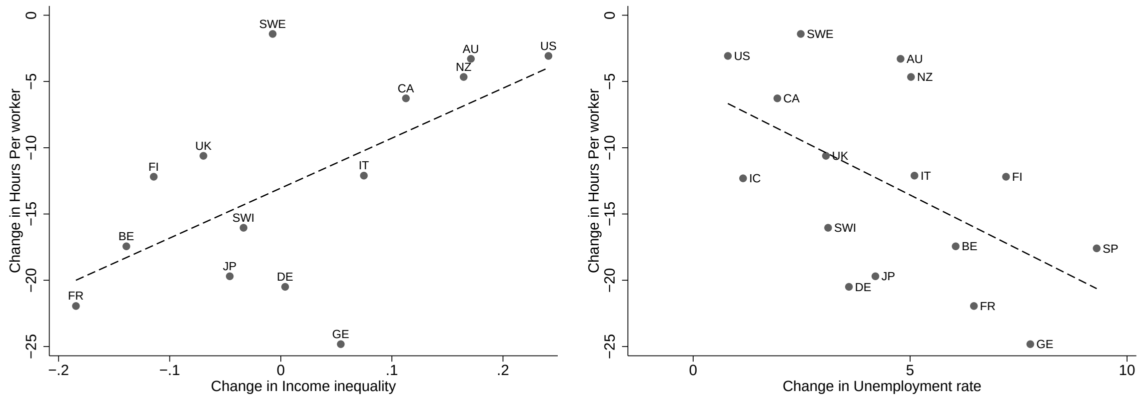
Fact 1 and 2 document the different evolution of the two main determinants of wage inequality. Fact 3 deals with unemployment dynamics. In figure 1 we plot the percentage change in hours worked per employee for selected OECD countries against the changes in earnings inequality (panel a) and in unemployment rate (panel b), respectively. Earnings inequality is measured as the log difference between the ninth and the first decile of the distribution of gross earnings of full-time workers in their main job. Changes are calculated over the 1970-2002 period. The correlation between changes in hours worked and changes in income inequality is around sixty percent. The analogous correlation with unemployment changes is again around sixty percent; both are statistically significant at a five percent level of significance. They also have independent explanatory power, since they remain significant (at a ten percent level) when simultaneously included in a regression explaining changes in working hours. Although just suggestive, this evidence hints at a potentially interesting link between working time decisions and labor market conditions. Since labor market conditions in the US and Europe have started to diverge mainly after the 70's, these considerations can help to explain why Europeans now work less than Americans, while they were working similar hours back in the 50's.[3]

We use data from the Panel Study of Income Dynamics (PSID) and the German Socio-Economic Panel (GSOEP) to analyze the evolution of the inter-temporal return to hours worked in the US and in Germany. In both countries we find that hours worked

[2]The rise in the EU unemployment rate is mainly explained by a fall in the exit rate from unemployment in the EU relative to the US. The job separation rate has instead remained roughly constant, both in the US and in the EU, see OECD (1997, chap. 5) for a review of the cross-country evidence.

[3]For example Germans were working longer hours than Americans in the 50's while they now work around 20% less hours than Americans. The Americans started to work longer hours than Germans in the mid 70's, see Bell and Freeman (1995).

Figure 1: Hours worked and labor market conditions



(a) Income Inequality and Hours per Worker (b) Unemployment Rate and Hours per Worker

Note: Changes over the 1970-2002 period. Source OECD, see "http://www.oecd.org". Changes in Hours per Worker are percentage changes in the average annual hours worked per employee in the 1970-2002 period. Changes in the unemployment rate are level variations over the same period. Changes in income inequality are calculated as variations in the log difference of the ninth and the first decile of the distribution of gross earnings in main job of full-time workers; the sample period used differs because of data availability. We always select the available data closest to 2002 and to 1970, respectively.

yield a significant inter-temporal return. Moreover, the inter-temporal return to working time has increased in the US since the 70's, while it has remained roughly constant in Germany (at least since the mid 80's, which is when the GSOEP starts). We argue that the different evolution of the return to skill and in within-skill wage inequality explains a substantial part of the different evolution of the return to hours worked.

Differences in the inter-temporal return to hours worked can contribute to explain differences in the evolution of working time in the US and the EU. To quantify the contribution of labor market conditions, we calibrate the model to match a variety of statistics on labor flows and wage dynamics at the micro level. We focus on prime age male workers because these workers are likely to actively engage in the labor market. We analyze the effects of increasing the return to skill and within-skill wage inequality so as to match the rise in wage inequality experienced by the US since the 70's. We then analyze the effects of reducing the reemployment probabilities of unemployed workers so as to reproduce the raise in unemployment in Continental Europe over the last thirty years. We find that the different evolution of the labor market in the US relative to the EU (in terms of inequality and unemployment) explain between one half and two thirds of the US-EU differences in the evolution of working time.

The idea that labor market conditions play a role in explaining working time differences is novel. Prescott (2004) attributes the relative fall in hours worked in Europe to the sharp increase in taxes experienced by several European countries. This tends to reduce the *net* return to hours worked and discourages working time. We provide evidence that the *gross* return to working longer hours has evolved differently across the two sides of the Atlantic. This suggests that taxes can not be the only reason why working time has evolved differently. Blanchard (2004) argues that Europeans work less than Americans because they have a stronger preference toward leisure. In our model this happens not because Europeans are intrinsically different from Americans, but because they lack career prospects due to the sluggish labor market. Alesina, Glaeser, and Sacerdote (2005) argue that trade unions introduced work sharing arrangements. They restricted the number of hours worked per employee so as to maintain a higher employment level. Our analysis suggests that the observed different evolution of wage inequality and unemployment in the US and the EU, could simply be part of a trade unions' attempt to make work sharing politically sustainable. Working time restrictions, imposed by law or collective bargaining agreements, become incentive compatible because Europeans do not prefer to work longer hours given the existing labor market conditions. OECD (1998, chap. 5) reports that the difference between actual and desired working time is generally small for European workers and it has even decreased over the last decades. Bell and Freeman (2001) also document that the fraction of workers that would prefer to work longer hours for given hourly wages is higher in the US than in Germany.

Our theory is also consistent with two facts about the distribution of hours worked per male workers, that are hard to reconcile with other explanations of the widening in the US-EU differential in hours: the increase in the fraction of US workers working very long hours (see Kuhn and Lozano (2005) and Costa (2000)) and the relative stability of such fraction in Continental European countries, see OECD (1998, chap. 5) and OECD (2004, chap. 1). In particular Kuhn and Lozano (2005) use data from the Current Population Survey for the US and document a sharp rise in the fraction of prime age male employees working more than 50 hours per week. Moreover, the fraction of men working long hours has increased more in occupations, industries and groups of workers (such as highly educated and high wage earners) that also experienced the sharpest increases in within skill wage inequality.

Our analysis is also related to Bell and Freeman (1995), and Bell and Freeman (2001). Bell and Freeman (1995) have also argued that higher wage inequality gives greater incentives to work longer hours. Looking at the NLSY for the US and at the GSOEP for Germany, Bell and Freeman (2001) show that occupations with larger wage inequality are also occupations in which individuals work longer hours. Our work complements these findings by showing that, at the individual level, higher work effort is associated to larger future income. We provide a model and specify an explicit channel whereby wage inequality affects the returns to working longer hours. Furthermore we investigate how several features of the labor market affect working time decisions aside from wage inequality and we quantify their role in accounting for the diverging evolution of working time in the US and the EU.

The idea that hours worked increase worker's human capital is not entirely novel. The idea has been formally put forward by Imai and Keane (2004). They use data from the NLSY to test a model of wage dynamics where hours worked increase the future labor earnings of the worker due to learning-by-doing. They show that hours worked are an important source of accumulation of human capital. Our work emphasizes that hours worked decisions interact with several salient features of the labor market when i) hours worked are a source of accumulation of human capital and ii) the labor market is subject to search frictions.

The plan of the paper is as follows. In the next section we describe a simple two period model that highlights how labor market variables affect the inter-temporal returns to hours worked and working time decisions. Section 3 extends the model to allow for recurrent unemployment spells and a general specification of technology and preferences. Section 4 calibrates the model. We use a variety of statistics calculated from PSID and GSOEP. Section 5 quantifies the role of labor market conditions in accounting for the diverging evolution of working time in the US and the EU. Section 6 considers some extensions. Section 7 concludes.

2 A two-period stylized model

In this section we study the determinants of the inter-temporal returns to hours worked. We show how labor market conditions affect working time decisions. We do so in a purposely very stylized model. There are two reasons for this. First, we want to highlight some basic channels whereby labor market conditions affect the inter-temporal returns to hours worked and the choice of hours. A more general model for quantitative analysis is presented in Section 3. Second, this simple model will naturally suggest ways to identify key parameters of the general model in the data. This will play an important role in the discussion on calibration in Section 4.

In this simple model the economy lasts for two periods. In the first period workers are employed. Their initial stock of human capital is $H \in \mathbb{R}_+$. By working h hours they produce an amount of efficiency units of labor $H^\alpha h^\theta$. The job remunerates efficiency units of work at rate ω. We refer to ω as to the *wage* rate of the job. Then the worker's income is $\omega H^{\alpha} h^{\beta}$. Next period's stock of human capital H' is related to the number of hours worked in the current period: $H' = a\, h$, where a is the rate at which human capital is accumulated. Note that for simplicity we are assuming that human capital gets fully depreciated over the period.

Next period workers are unemployed with probability ϕ. In practice ϕ is the joint probability that a worker becomes unemployed *and* that he does not find a new job in the period. Thus ϕ is increasing in the job separation probability and decreasing in the job finding probability. An unemployed worker obtains logged income that yields him utility equal to b.

If the job is not destroyed, the worker can receive a job offer from a firm that pays a wage ω'. Job offers are received with probability $p_e(H')$, which is increasing in the stock of the worker's human capital H'. This captures the idea that high skilled workers can obtain better job offers than low skilled workers. The job offer probability p_e should be interpreted as the product of a parameter related to the tightness of the labor market and the number of efficiency units of search of the worker—the latter being increasing in the stock of human capital of the worker. Job offers are a random draw from a given wage distribution $F(\omega)$. The distribution F captures within-skill wage inequality. In equilibrium workers will accept offers whenever $\omega' > \omega$. For simplicity we assume that the wage offer distribution has mass $1-q$ at the point ω_1 and q at the point ω_2, with $\omega_1 < \omega_2$.

Preferences over consumption and leisure are given by the following utility function,

$$u(c, \lambda h) = \ln c - \lambda h.$$

where λ measures the effort cost of working. This choice of preferences implies that the income and the substitution effects cancel out exactly, so that permanent wage changes have no effects on hours worked. For simplicity we assume that workers do not save and can not borrow. Therefore, consumption is simply equal to labor income.

We start to solve the model backwards. In the second period the problem of the workers is given by

$$V_2(\omega', H') = \max_{h'} \left\{ \ln\left(\omega' H'^{\alpha} h'^{\theta}\right) - \lambda h' \right\},$$

which implies the following simple expression for the optimal choice of hours:

$$h' = \frac{\theta}{\lambda}.$$

Substituting this result into the previous expression yields

$$V_2(\omega', H') = \ln\omega' + \alpha \ln H' + \theta \ln\theta - \theta \ln\lambda - \theta. \tag{1}$$

In the first period the optimal choice of hours h for a worker with human capital H in a job with wage ω can be obtained by solving the following Bellman equation:

$$\begin{aligned} V_1(\omega, H) &= \max_h \Big\{ u\left(\omega H^\alpha h^\theta, h\right) + \beta\phi b + \beta(1-\phi) V_2(\omega, H') \\ &+ \beta(1-\phi) p_e(H') \int_{\mathbb{R}} \max\{V_2(s, H') - V_2(\omega, H'), 0\}\, dF(s) \Big\} \\ &\text{subject to} \\ &H' = ah. \end{aligned} \tag{2}$$

Using our simple wage offer distribution we can rewrite $V_1(w, H)$ as

$$V_1(\omega, H) = \max_h \Big\{ \ln\left(\omega H^\alpha h^\theta\right) - \lambda h + \beta\phi\, b + \beta(1-\phi)\left[V_2(\omega, H') + p_e(H')\, q\,(\ln\omega_2 - \ln\omega)\right] \Big\}$$

Then, the first order condition for h reads as

$$\lambda = \frac{\theta}{h} + \beta(1-\phi)\left[\frac{\alpha}{h} + \frac{dp_e}{dH'}\, a\, q(\ln\omega_2 - \ln\omega)\right], \tag{3}$$

which says that hours worked are chosen by equating the marginal disutility of working to the marginal return of an hour of work. The marginal return is the sum of the value of the marginal increase in current income, equal to θ/h, and the expected marginal increase in future income—which corresponds to the second term in the right hand side of equation (3). There are two different components in the inter-temporal returns to hours worked. First, the return to skill, α. Second, the expected increase in income due to a job offer. It is to this second channel that inequality in jobs is related. Additionally, both effects depend on the rate of utilization of human capital, $(1-\phi)$. Therefore, the marginal increase in future income is zero if both the return to skill, α, is zero, and hours worked do not increase the stock of human capital, $a = 0$. It is also zero if the worker is unemployed with probability one in the next period. To obtain an explicit expression for h we log-linearize the function describing the probability of getting an offer :

$$p_e(H') \simeq p_0 + p_1\left(\ln H' - \ln\overline{H}\right) \tag{4}$$

where $\overline{H}$ is an appropriately defined constant while p_1 is the semi elasticity of the job offer probability to the stock of human capital. In general p_1 is higher in a tighter labor market, since search efficiency units are more effective when labor market tightness rises. This allows to solve for h so as to obtain that

$$h = \frac{\theta + \beta (1 - \phi) [\alpha + p_1 q (\ln \omega_2 - \ln \omega)]}{\lambda}. \tag{5}$$

Notice that the intra-temporal return to hours worked (the first term in the numerator of the right-hand side of equation (5) is independent of ω. This is because with log preferences the income and the substitution effect cancel out. The inter-temporal return to hours worked (the second term in the numerator) is instead decreasing in ω, because the chances of obtaining a better job decrease as the current wage rate increases. This discourages working time. The inter-temporal return to hours worked is also decreasing in the unemployment probability ϕ, because a higher ϕ reduces the rate of use of the accumulated stock of human capital H', while it is increasing in the rate of return to human capital α. Thus:

1. The amount of hours worked is higher in a tighter labor market—i.e. when the unemployment probability ϕ is smaller or p_1 is higher.

2. The amount of hours worked is higher if within-skill wage inequality, modeled as a mean preserving spread in the wage offer distribution F, increases.

3. The amount of hours worked increase if the return to skill α rises.

2.1 Some preliminary evidence

The central testable implication of the model is that current hours of work raise future income. Furthermore, since wage inequality has increased in the US and remained roughly constant in the EU, another implication is that this effect has increased in the US, while it has changed little in Europe. We present some preliminary evidence supporting these predictions based on panel data at the micro level. In the next section we consider an extended model and we quantify the importance of labor market conditions in accounting for the diverging evolution of working time in Europe and the US.

We estimate an equation relating hourly wages to current and past hours. The equation can be explicitly motivated by considering the two-period model just discussed. Consider the second period logged hourly wage. This is the difference of log income and log hours:

$$\ln w' = [\ln \omega' + \alpha \ln H' + (\theta - 1) \ln h'] . \tag{6}$$

The log of the wage rate $\ln \omega'$ evolves as

$$\ln \omega' = \ln \omega + p_e(H')\, q\, (\ln \omega_2 - \ln \omega) + \epsilon$$

where ϵ denotes a zero mean expectational error. Now use equation (4) to approximate $p_e(H')$ and then linearize the resulting expression with respect to $\ln H'$ and $\ln \omega$ around $\ln \bar{H}$ and the average logged wage rate $\ln \overline{\omega}$. Using equation (2) to express H' in terms of h we obtain:

$$\ln \omega' \simeq cte + p_1 q\, (\ln \omega_2 - \ln \overline{\omega}) \ln h + (1 - p_0 q) \ln \omega + \epsilon \tag{7}$$

where *cte* is an appropriately defined constant. By using the expression for logged hourly wage at time zero,

$$\ln w = \ln \omega + \alpha \ln H + (\theta - 1) \ln h,$$

we can obtain an expression for $\ln \omega$ that can be substituted into (7). The resulting expression can then be used to substitute out $\ln \omega'$ in (6) so as to obtain

$$\ln w' = cte + (1 - p_0 q)\, \ln w - (1-\theta) \ln h' + [\alpha + p_1 q\, (\ln \omega_2 - \ln \overline{\omega}) + (1-\theta)(1 - p_0 q)] \ln h + \varepsilon \tag{8}$$

where again *cte* denotes an appropriately defined constant whose exact value is omitted to save space and $\varepsilon \equiv \epsilon + \alpha\,(1 - p_0 q) \ln H$. This relation suggests estimating the following equation:

$$\ln w_{i,t} = \psi_0 + \psi_1 \ln w_{i,t-1} + \psi_2 \ln h_{i,t} + \psi_3 \ln h_{i,t-1} + \varepsilon_{i,t} \tag{9}$$

Hours of work increase future income if $\psi_3 > 0$. Note that equation (8) implies that the coefficient on past logged hours is positive only if there is a significant inter-temporal return to working longer hours. For our empirical work hours and wages are measured as five years averages to purge their dynamics from business cycle effects. We estimate the equation by both standard OLS and fixed effect methods. This is because the error term in equation (8) could contain an unobserved individual fixed effect term, which may be correlated with $\ln y$ and $\ln h$. Fixed effects estimates are based on the two-step Arellano and Bond (1991) estimator (difference GMM estimator). Standard errors are corrected for finite sample bias as in Windmeijer (2005). In the regressions we also control for education and experience. These controls have no counterpart in our simple model, but are regarded as important in the empirical literature.

We estimate equation (9) for both the US and Germany. The US data come from the Michigan Panel Study of Income Dynamics (PSID), which covers the period 1967-2002. Data are annual up to 1997 and bi-annual thereafter. We restrict our samples to prime

Table 1: The inter-temporal returns

A) PSID

Hours measure:	Annual [1]	Annual [2]	Usual weekly [1]	Usual weekly [2]
ψ_1	0.81	0.48	0.81	0.43
	(192.4)	(3.57)	(189.2)	(2.7)
ψ_2	-0.43	-0.56	-0.35	-0.56
	(-41.4)	(-10.5)	(-34.2)	(-10.1)
ψ_3	0.51	0.42	0.49	0.75
	(45.7)	(5.3)	(35.06)	(4.2)
n	31,636	28,105	31,633	28,101

B) GSOEP

Hours measure:	Annual [1]	Annual [2]	Usual weekly [1]	Usual weekly [2]
ψ_1	0.65	0.15	0.67	0.09
	(73.76)	(2.0)	(73.8)	(1.4)
ψ_2	-0.63	-1.05	-0.64	-1.03
	(-24.7)	(-11.0)	(-24.2)	(-10.2)
ψ_3	0.56	0.23	0.61	0.24
	(23.1)	(2.9)	(22.9)	(2.1)
n	6,371	5,515	6,120	5,261

In column [1] OLS estimates, in column [2] fixed effects estimates. Fixed effects estimates are based on two steps Arellano and Bond (1991) estimator (difference GMM estimator). Standard errors are corrected for finite sample bias as in Windmeijer (2005). t-statistics in parentheses. The dependent variable is the logged real hourly wage. Hours and wages are measured as five years averages. Instruments are lagged values of past five years averages. All regressions include year and education dummies and potential experience (in levels and squared).

age male (between 25 and 55 years old) who are head of households. We focus on these workers because they are most likely to actively engage in the labour market; this reduces sample selection problems related to labor market participation, which is an issue not explicitly analyzed in the model. Hourly wages are computed as annual labor earnings divided by annual hours worked. We consider two measures for hours worked. The first denoted *Yearly hours* is the total annual hours worked for money by the worker in any job. The second denoted *Weekly hours* is the number of hours usually worked per week in the main job, when at work. Labor income measures are in real terms by deflating them with the output deflator. We express them in 1992 dollars. Table 14 in the appendix contains some descriptive statistics for the baseline sample. We will also consider measures of the number of years of schooling and potential experience (measured as current age minus years of schooling), see Appendix for further details. The German data come from the German Socioeconomic Panel (GSOEP). The data refer to the period 1984-2002. Again we restrict our sample to prime aged male (between 25 and 55 years old) who are head of households and who reside in the former Federal Republic of Germany, see Appendix for further details.

Table 1 presents the results. The upper panel contains the results for the US, the lower panel for Germany. The columns labeled as [1] are OLS regressions. We find that ψ_3 is positive and statistically significant. This is true for both the US and Germany and independently of whether we consider yearly or weekly hours. The coefficients ψ_2 is greater in absolute value in Germany than in the US, while ψ_3 is similar in the two economies. In Germany current income in many jobs is influenced by collective agreements, and it is set independently of the number of hours worked in the period. So workers can raise their labor income by either obtaining better jobs or getting promoted in the current one. This may explain why hourly wage in the current job decrease faster in Germany than in the US when current hours increase. As a result, in Germany the inter-temporal return to hours worked is always relatively more important than the intra-temporal return.

The columns labelled as [2] report estimates based on the two-step Arellano-Bond estimator. Instruments are lagged values of past five years averages. Now the estimated serial correlation of wages as measured by ψ_1 falls significantly relative to the OLS estimates. But the estimated ψ_3 is again positive, statistically significant and of a very similar magnitude at least for the US. This evidence complements the findings of Bell and Freeman (2001) and Kuhn and Lozano (2005), who found a positive correlation between hours of work and income inequality. Our theory provides a causal interpretation for their finding.

As argued in the introduction, both the returns to skill and residual wage inequality have increased sharply in the US while they have hardly changed in Europe. According to our model, the inter-temporal return to working time should have increased in the US while it should have changed little in Europe. In particular, if α and $(\ln \omega_2 - \ln \bar{\omega})$ increase, equation (8) predicts that ψ_3 should increase too. To check this, we estimate again equation (9) while allowing for a time-changing coefficient ψ_3. We allow the coefficient to change every five or ten years, depending on the specification. The results are presented in Table 2. In column [1] we report the OLS estimates, in column [2] the fixed effects estimates. The upper panel deals with the PSID, the lower panel with the GSOEP. For the US, we find that ψ_3 has increased over time. A formal statistical test shows that the inter-temporal returns to hours worked are larger in the 90's than in the 80's and in the 70's. For Germany, the inter-temporal returns are instead larger in the 80's than in the 90's although this difference is not statistically significative.[4]

[4]Since several authors have argued that in the US the return to education and experience have in-

Table 2: Evolution of the intertemporal return

A) PSID

Hours measure:	Annual [1]	Annual [2]	Usual weekly [1]	Usual weekly [2]
$\psi_{3,70-75}$	0.43	0.41	0.44	0.58
	(15.7)	(4.9)	(12.8)	(4.6)
$\psi_{3,76-80}$	0.47	0.41	0.47	0.58
	(21.0)	(5.3)	(16.5)	(4.7)
$\psi_{3,81-85}$	0.46	0.40	0.42	0.56
	(22.1)	(5.1)	(14.8)	(4.5)
$\psi_{3,86-90}$	0.51	0.41	0.49	0.56
	(28.0)	(5.4)	(20.1)	(4.4)
$\psi_{3,91-95}$	0.58	0.50	0.61	0.67
	(29.1)	(5.8)	(24.3)	(4.7)
$\psi_{3,96-00}$	0.60	0.51	0.59	0.64
	(13.3)	(5.5)	(10.1)	(4.6)
$\psi_{3,70-80}$	0.46	0.42	0.45	0.75
	(25.1)	(5.3)	(20.1)	(4.3)
$\psi_{3,81-90}$	0.49	0.40	0.45	0.74
	(33.7)	(5.3)	(23.6)	(4.2)
$\psi_{3,91-00}$	0.59	0.50	0.61	0.86
	(31.4)	(5.6)	(25.9)	(4.6)
Test:				
$\psi_{3,70-80} = \psi_{3,81-90}$	.17	.39	.50	.50
$\psi_{3,70-80} = \psi_{3,91-00}$	.00	.07	.00	.09
$\psi_{3,81-90} = \psi_{3,91-00}$	.00	.00	.00	.03

B) GSOEP

	Annual Hours [1]	Annual Hours [2]	Usual weekly hours [1]	Usual weekly hours [2]
$\psi_{3,84-88}$	0.53	0.27	0.57	0.30
	(13.0)	(3.1)	(14.0)	(2.5)
$\psi_{3,89-93}$	0.60	0.27	0.71	0.30
	(19.1)	(2.8)	(19.6)	(2.0)
$\psi_{3,94-98}$	0.57	0.22	0.56	0.26
	(15.3)	(2.9)	(14.3)	(2.0)
$\psi_{3,84-91}$	0.58	0.25	0.63	0.28
	(19.3)	(2.9)	(20.0)	(1.97)
$\psi_{3,92-02}$	0.56	0.19	0.58	0.22
	(17.8)	(2.3)	(17.1)	(1.8)
Test:				
$\psi_{3,85-92} = \psi_{3,93-02}$	.63	.09	.17	0.10

Note: In column [1] OLS estimates, in column [2] fixed effects estimates. Fixed effects estimates are based on the two steps Arellano and Bond (1991) estimator (difference GMM estimator). Standard errors are corrected for finite sample bias as in Windmeijer (2005). Instruments are lagged values of past five years averages. t-statistics in parentheses. All regressions include year dummies and controls for education and potential experience and we allow for a time varying return to education and experience. The first two columns use total annual hours in all jobs whereas the second two columns use usual weekly hours worked in main job. Hours and wages are measured as five years averages.

3 The general model

To quantitatively study how much labor market conditions can explain of the different evolution of working time in the US and Europe, we now extend the model in several directions. First, we allow individuals to experience recurrent unemployment spells. Second, we allow for an endogenous unemployment exit probability. Third we consider the possibility that hours worked exhibit a downward trend over time. Finally, we consider more general functional forms for preferences and technology. The first extension is introduced to analyze separately the effects of the job separation rate and the job finding rate on working time decisions. The second implies that unemployment exit rates are affected by workers' skills. The third is introduced to match the secular downward trend for hours worked per employee observed in the US data, see McGrattan and Rogerson (1998) and McGrattan and Rogerson (2004). The last extension is introduced to match key features of the data.

3.1 Model description

Workers are infinitely lived. An employed worker is characterized by her stock of human capital $H \in \mathbb{R}_+$ and by the job wage rate $\omega \in \mathbb{R}_+$. When employed, the worker decides how many hours to work. Hours of work generate a flow of income $\omega H^\alpha h^\theta$ in the current period and increase the stock of human capital in the next period, $H' = (1 - \delta) H + a_t h$, where $\delta \in [0, 1]$ is the depreciation rate of human capital and a_t is the contribution of one hour of work to human capital accumulation at time t. Due to skill augmenting technological progress we assume a_t to increase over time.

Between any two periods, three events may happen to the employed worker: she may lose her job, she may receive another job offer or nothing new happens. The job separation rate is given by p_s. The probability of receiving a job offer is given by $p_e (H')$. Thus greater human capital allows the worker to obtain better jobs. Workers accept job

creased over time, we have also considered an alternative specification where education and experience are interacted with time dummies. This allows the return to experience and education to change over time. We find that results remain unchanged. To save space we do not report them.

offers that yield them greater value. The problem of an employed workers reads as follows:

$$\begin{aligned} W_t(\omega, H) &= \max_h \Big\{ u(c, \lambda_t h) + \beta p_s V_{t+1}(H') + \beta(1-p_s) W_{t+1}(\omega, H') \\ &+ \beta(1-p_s) p_e(H') \int_{\mathbb{R}} \max\left[W_{t+1}(s, H') - W_{t+1}(\omega, H'), 0\right] dF(s) \Big\} \end{aligned} \tag{10}$$

subject to

$c = \omega H^{\alpha} h^{\theta}$

$H' = (1-\delta) H + a_t h$

where λ_t measures the effort cost of working at time t. We assume this to be increasing in time to match the observed secular downward trend of hours worked for male workers in the US. To focus the analysis on a situation where hours worked fall at a constant rate μ over time, we assume that $\frac{\lambda_t}{a_t} = \lambda$ and $\lambda_t = \lambda(1+\mu)^t$. The parameter $\beta \in (0,1)$ is the inter-temporal discount factor and $V_t(H)$ is the value of unemployment at time t, that depends just on the worker's stock of human capital and time (because of the time changing value of a_t and λ_t).

An unemployed worker receives a job offer with probability p_u. In that case he decides whether to accept it or not. Thus the decision problem is characterized by a reservation wage rate ω_r such that only wage offers above ω_r are accepted. The problem of an unemployed worker can then be expressed as follows:

$$V_t(H) = \max_{\omega_r} \left\{ b + \beta\Big[1 - p_u(1 - F(\omega_r))\Big] V_{t+1}(H') + \beta p_u \int_{\omega_r}^{\infty} W_{t+1}(s, H') dF(s) \right\} \tag{11}$$

subject to

$H' = (1-\delta) H$

where $b \equiv u(y_u, h_u)$ is the utility while unemployed, which is the result of some unemployment income y_u and the hours h_u that have to be devoted to the job search activity.

3.2 Functional forms

Preferences between leisure and consumption are given by,

$$u(c, \lambda h) = \ln c - \frac{(\lambda h)^{1+\eta}}{1+\eta}, \quad \eta \geq 0$$

where η affects the sensitivity of the marginal disutility of working to hours worked.

The probability of receiving job offers is given by:

$$p_e(H) = \bar{p}_e \frac{1+\gamma_0}{1+\gamma_0 e^{-\gamma_1 H}}, \quad \gamma_0, \gamma_1 \geq 0$$

We think of $\bar{p}_e$ as the probability of receiving a job offer for a given search efficiency unit. The parameter γ_1 gauges how human capital affects workers' ability to search in the labor market. When γ_1 is equal to zero, human capital has no effects on search efficiency. The parameter γ_0 characterizes instead the flexus point of the function. When γ_0 is smaller than one the function is globally concave on the positive real line. For larger values of γ_0 the function is s-shaped. We use a logistic function to model how the job offer probability is related to the stock of human capital, because it does not impose any constraint on the (average) value of the semi-elasticity of p_e with respect to H.[5]

We assume that the distribution of job offers F is log normal with variance ν:

$$\log \omega \sim N(0, \nu)$$

This formulation implies that the mean of the wage offer distribution (in levels) is equal to 1 and the variance equal to $e^{\nu} - 1$.

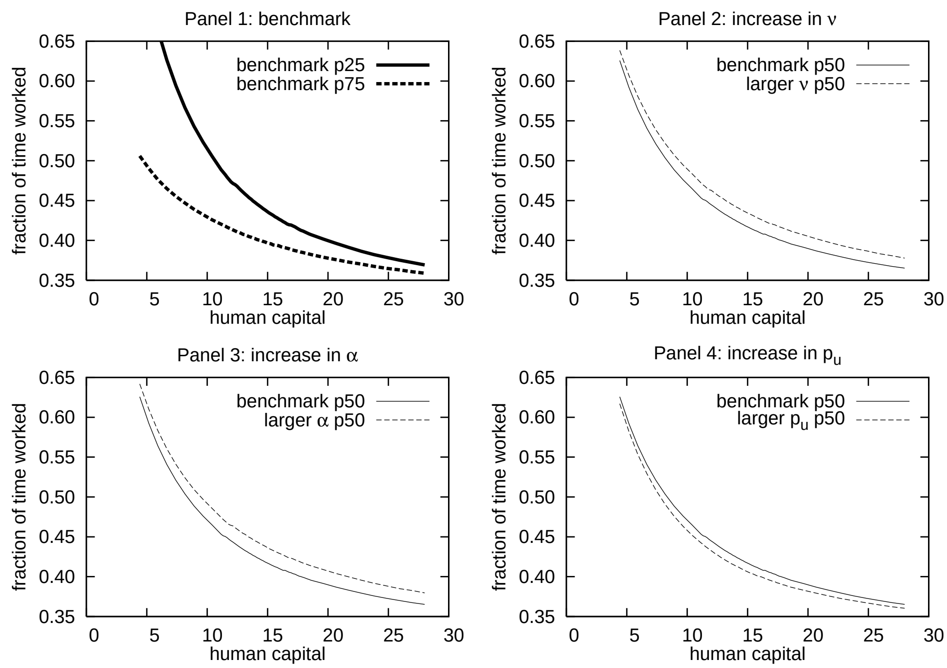
3.3 Solution of the model

The solution to the individual problem described in section 3.1 is given by a pair of stationary decision rules $g^{\omega_r}(H)$ and $g^h(\omega, H)$ that determine the reservation wage policy of an unemployed worker and hours worked relative to the trend $(1+\mu)^{-t}$ of an employed worker, respectively. Figure 2 plots the decision rule $g^h(\omega, H)$ for some specific parameters value. The numerical example is provided only for illustrative purposes. A formal quantitative exercise will be conducted in section 4.

Panel 1 plots the decision rule for employed workers as a function of the worker's stock of human capital H for given ω. The solid line corresponds to a low value of ω whereas the dotted line to a high value of ω. We observe that the decision rule is decreasing in H: the greater the stock of human capital, the lower is the amount of hours worked. This is because a given amount of hours worked cause smaller percentage increases in the stock of human capital when this is high. With log preferences this reduces the incentive of working longer hours. Comparing the two schedules in Panel 1 we observe that individuals

[5]For example imposing a generic concave function with positive intercept would implicitly limit the value of the semi-elasticity at given levels of the stock of human capital and of job offer probability

Figure 2: Policy functions



with lower ω work longer hours. This arises because they want to obtain better jobs. The difference is less pronounced when the stock of human capital is low. When H is high all workers work the same number of hours. This is because, with high H, increasing human capital increases little the probability of job offers (p_1 in Section 2 goes to zero when H goes to infinity).

Figure 2 also shows the effect on individual behavior of a mean preserving spread in the wage offer distribution, ν (panel 2), of an increase in the returns to skill α (panel 3) and of an increase in the reemployment probability p_u. An increase in ν and α shift the policy functions upwards and increase the incentives to work longer hours whereas the increase in p_u shifts the policy function downwards and discourages individuals from working longer hours.

The economy is fully characterized by the distribution of individuals over their state space. We focus on steady states. Let X_e denote the probability measure of workers in the corresponding state if employed. Then the average number of hours worked per worker relative to the trend can be expressed as

$$E[h] = \int_{\mathbb{R}_+^2} g^h(\omega, H)\, dX_e$$

This expression implies that changes in the shape of the cross-sectional distribution affect the average number of hours worked per worker. We now study how labor market conditions determine aggregate hours worked by taking into account effects on policy functions and on the cross-sectional distribution.

4 Calibration

We calibrate the model to the U.S. economy in the 70's. The model neglects labor force participation decisions, so we focus on prime age male workers since these workers are likely to actively engage in the labor market. Our choice of length for the model period is one month. Calibrating the model at a quarterly or at a yearly frequency would fail to properly characterize key labor market transitions. For instance, according to Shimer (2005) and Fallick and Fleischman (2001), the average duration of unemployment is between 2 and 3 months. Whenever the available data comes at yearly level we aggregate our simulated data to the same frequency. The downward trend in hours worked is set to replicate the average fall in hour worked per male worker over the period 1950-1970. McGrattan and Rogerson (2004) use US Census data and report that the average weekly hours worked per prime age male worker has fallen from around 45 hours to 43.5 hours over the 1950-1970 period. This implies a fall of around 3.5 percentage points over a twenty year period, which suggests $\mu = 0.0001485$ at the monthly frequency.

Our model is described by 14 parameters: 4 of them refer to preferences, 4 to transition probabilities, 1 to the job offer distribution, 4 to technology and finally there is one parameter that describe the unemployment state. 7 of these parameters are chosen either as normalization conditions, to simplify the model or just set off the shelves. The remaining 7 parameters are estimated such that the model matches 7 moment conditions from data. We use as targets a set of statistics obtained from some other empirical studies and from some micro data from the US. Indeed, this process can be seen as estimation by indirect inference. To help the reader, the parameters are listed in Table 6 and the targets used in the calibration are summarized in Table 7.

Preferences. We set η, the curvature of the marginal utility of leisure, equal to 2. This implies a Frisch elasticity of labor supply equal to 0.5, which is just a bit above most micro studies for prime age male workers actively engaged in the labor market. We set β, the discount factor, equal to 0.9966. This follows Hagedorn and Manovskii (2005). The value of λ, which determines the relative weight of leisure in the utility function, is chosen so that the average fraction of time spent at work is 0.4. This is the value we find in our sample.

Labor market transitions. We have three transition probabilities and four parameters. According to Shimer (2005), at the monthly level the separation rate is around 3.4% and the probability of finding a job for the unemployed is around 45%. We interpret the event of accepting a new job offer when employed as a job to job transition. [6] Under this interpretation, our third moment condition comes from Fallick and Fleischman (2001). They report that every month 2.8% of male workers experience a job-to-job transition.

Our fourth condition comes from the PSID. To identify γ that determines how on-the-job offers are related to the stock of human capital accumulated through past hours. To identify γ we rely on the relationship between past hours worked and the probability of a job-to-job transition. We construct a dummy variable that equals one if the individual experiences a job-to-job transition in the following year. We regress this variable against the log of the average hours worked by the individual in the past five years:

$$\text{job-to-job} = \text{cte.} + \psi_4 \ln h$$

One prediction of our model is that past hours worked increase the probability of a job to job transition. We use the PSID to evaluate this effect. Table 3 presents the results. In the regressions we also control for education and experience. These controls have no counterpart in our simple model, but are regarded as important in the empirical literature. We find that in the US ψ_4 is around 0.03. When we look at the GSOEP, we find that in Germany ψ_4 lies between 0.06 and 0.07. We estimate γ by indirect inference. We simulate data from the model, we aggregate the job to job transition and hours worked at the annual frequency, we construct five year averages of the hours worked by the individual and we then run the same regression as in the PSID data but with the model generated data. We choose γ so that the estimated coefficient ψ_4 using model generated data equals its analogue estimated in the PSID.

[6]This is not uncontroversial since the mechanics of the model may work though offers and counter-offers, without the worker having to change his job.

Table 3: Probability of getting a better job

A) PSID

Hours measure:	Annual	Usual weekly
Log past hours	0.03	0.02
	(4.22)	(2.64)

B) GSOEP

Hours measure:	Annual	Usual weekly
log past hours	0.05	0.07
	(4.37)	(5.46)

*N*ote: OLS regressions. *t*-statistics in parentheses. All regressions include year and education dummies and potential experience (in levels and squared). Logged Real Hourly wage before transition. Hours and wages are measured as five years averages.

Wage Offer distribution. The wage offer distribution is fully characterized by ν. We calibrate its value in equilibrium to match the dispersion of start-up wages after an unemployment spell. Table 4 present the evolution of these statistics in the PSID and GSOEP data. In the US, we measure the standard deviation of log wages after unemployment to be around 0.5 in the 70's and around 0.75 in the 90's. In contrast, in Germany we do not observe any increase in the dispersion of start-up wages upon re-employment.

Technology. We have four technology parameters: α, θ, δ, and the initial value of a. We normalize a to one and solve the economy for different values of δ. To determine α and θ we notice that hourly wages are given by $w = \omega H^{\alpha} h^{\theta-1}$. For individuals who do not change job and do not experience unemployment spells we can express the within job wage increase as,

$$\Delta \ln w_{i,t} = \alpha \Delta \ln H_{i,t} - (1-\theta) \Delta \ln h_{i,t} \tag{12}$$

After constructing a measure for the stock of human capital, this equation allows to identify α and θ. We use the human capital accumulation equation to construct a synthetic measure of the stock of human capital for every individual at every moment in time. The construction of the measure involves setting a value for the depreciation rate of human capital. Then we regress,

$$\Delta \ln w_{i,t} = \text{cte.} + \psi_5 \Delta \ln H_{i,t} + \psi_6 \Delta \ln h_{i,t} + \varepsilon \tag{13}$$

Table 4: Dynamics of SD of start-up wages after unemployment

A) PSID

Controls	Only time dummies	More controls
$SD_{3,70-80}$	0.52	0.49
$SD_{3,81-90}$	0.62	0.58
$SD_{3,91-02}$	0.77	0.70
n	55,000	54,681

B) GSOEP

Controls	Only time dummies	More controls
$SD_{3,84-91}$	0.43	0.43
$SD_{3,92-02}$	0.43	0.42
n	6,321	6,321

*N*ote: Standard Deviation of logged real hourly wage of workers who experienced an unemployment spell in the year. In column 2 we also control for years and education dummies, tenure (in levels and squared) and potential experience (in levels and squared).

We use PSID data and we run this regression by selecting all workers that remain in the same job for two consecutive years. Given equation (12), we then set $\alpha = \psi_5$ and $\theta = \psi_6 - 1$ as an approximation.[7] Table 5 reports the estimates with PSID data when the synthetic stock of human capital is constructed using different values for the (annual) depreciation rate of human capital. The estimate suggests a value of α around seven per cent and a value of θ around 30 percent.

Unemployment. We choose the utility while unemployed b, so that unemployed workers accept on average 90 percent of the job offers they receive. This is in line with the acceptance rate reported by Barron, Bishop, and Dunkelberg (1985) using information on

[7]The mapping between the model parameters and the estimated coefficients would be exact if we could perfectly measure the stock of human capital and if the data were at the monthly frequency as in the model. Alternatively we could estimate α and θ by indirect inference. We could simulate data from the model, aggregate the data at the annual frequency, construct an analogous synthetic measures of human capital in the simulated data, then run the same regression as in the actual data and finally search for the pair of α and θ that make the estimated coefficients using model generated data equal to those obtained in the PSID data. We avoid presenting the result with this strategy just for simplicity. The estimated α and θ under this alternative strategy would be very similar to those in the baseline specification. For example, in our baseline specification (with high δ, see below) we find that when we run the regression (13) with model simulated data the coefficient ψ_5 is 5.8 per cent while ψ_6 is minus 72 per cent.

Table 5: Determination of α and θ, PSID

Annual δ:	$\delta = 0.1$	$\delta = 0.3$	$\delta = 0.5$
$\Delta \ln H$	0.05	0.065	0.073
	(4.6)	(5.7)	(6.5)
$\Delta \ln h$	-.68	-.68	-.68
	(-94.7)	(-94.7)	(-94.7)
Time evolution			
$\Delta \ln H_{70-80}$	.038	.043	.070
	(1.9)	(2.0)	(3.5)
$\Delta \ln H_{81-90}$	.044	.056	.079
	(2.9)	(3.4)	(5.2)
$\Delta \ln H_{91-00}$	.068	.102	.135
	(4.6)	(5.1)	(7.9)
n	16,019	16,019	16,019
Test:			
$\psi_{1,70-80} = \psi_{1,81-90}$	.85	.65	.82
$\psi_{3,81-90} = \psi_{3,91-00}$	.20	.03	.02

Note: OLS estimates. t-statistics in parentheses. All regressions include year and education dummies and potential experience (in levels and squared). The dependant variable is the within job real wage growth of workers. In the lower panel education and experience are interacted with time dummies to allow their return to change over time.

the number of job offers turned down by workers in the US.[8]

4.1 Parameters value

From the previous analysis it follows that we have 7 parameters to determine in equilibrium: λ, ψ, $\bar{p}_e$, p_u , p_s, ν, and b. The values of these calibrated parameters appear, along with all the rest, in Table 6. We analyze two different economies that differ in the depreciation rate of human capital. In the former δ is set to 1 percent per month, in the latter to 2.5. We will refer to the first case as the low depreciation economy, to the second as the high depreciation economy.

In table 7 we summarize the statistics from the data used for the calibration. We also report the analogous statistics generated from the model economy. The model fit is very good.

[8] Blau and Robins (1990) instead report an acceptance rate of 70 percent, which is slightly lower. The differences between the two numbers is due to the different source of information: Barron, Bishop, and Dunkelberg (1985) use employer data while Blau and Robins (1990) worker data. We rely Barron, Bishop, and Dunkelberg (1985) because employer data are arguably more reliable.

Table 6: Parameter values in baseline calibrations

Parameter	definition	value low δ	value high δ	type of fit
β	patience	0.9966	0.9966	direct
σ	curvature consumption	1	1	direct
η	curvature leisure	2	2	direct
λ	weight leisure	11.115	9.684	equilibrium
γ	slope probability offers	0.515	0.266	equilibrium
$\bar{p}_e$	average tightness, employed	0.129	0.131	equilibrium
p_u	job offer probability, unemployed	0.500	0.500	equilibrium
p_s	separation probability	0.034	0.034	direct
ν	variance log ω	0.295	0.285	equilibrium
α	hours elasticity	0.075	0.075	direct
θ	human capital elasticity	0.300	0.300	direct
δ	depreciation H	0.010	0.025	equilibrium
a	learning-by-doing rate	1.000	1.000	direct
b	utility while unemployed	-3.274	-3.264	equilibrium

Table 7: Model and data statistics

Statistic	data	model
Average hours worked	0.395	0.395
Standard deviation of reemployment log wages	0.500	0.500
Average separation rate	0.034	0.034
Average prob. of a job-to-job transition	0.028	0.028
Elasticity of job-to-job transition to H	0.060	0.060
Average prob. leaving unemployment	0.450	0.450
Average acceptance rate of offers by unemp.	0.900	0.900

5 The evolution of hours worked in the US and EU

The aggregate number of hours worked per capita has evolved quite differently in the US and in Continental Europe over the 1970-2001 period. Changes in aggregate hours my be due to changes in the unemployment rate, in the participation rate, in hours worked per worker or in the fraction of working age population over the total population. In brief aggregate hours worked per capita can be decomposed as follows:

$$\frac{\text{hour}}{\text{pop}} = \frac{\text{hour}}{\text{emp}} \times \frac{\text{emp}}{\text{part}} \times \frac{\text{part}}{\text{wa}} \times \frac{\text{wa}}{\text{pop}}$$

where 'hour', 'pop', 'emp', 'part', and 'wa' denote the aggregate number of hours worked, total population, the number of employed workers, the size of the labor force and of the working age population, respectively. The percentage changes of the various components underlying the dynamics of 'hour' over the period 1970-2001 for some selected countries are summarized in Table 8. The table evidences how aggregate hours worked per worker accounts for around 50 per cent of the differences in aggregate hours worked per capita in the US and in France, Germany, Spain, and Italy.

Table 8: Evolution of aggregate hours worked, Total (1970-2001)

	$\frac{\text{hour}}{\text{pop}}$	$\frac{\text{hour}}{\text{emp}}$	$\frac{\text{emp}}{\text{part}}$	$\frac{\text{part}}{\text{wa}}$	$\frac{\text{wa}}{\text{pop}}$
Absolute Percentage Changes					
U.S.	15	-5	0	13	7
France	-22	-23	-6	3	4
Germany	-24	-26	-7	4	6
Italy	-14	-14	-4	4	2
Spain	-6	-14	-9	10	10
U.K.	-8	-12	-3	4	4
Japan	-14	-19	-4	11	-1
Percentage changes relative to the US					
U.S.	0	0	0	0	0
France	-37	-17	-6	-10	-3
Germany	-39	-21	-7	-9	-1
Italy	-29	-9	-4	-9	-6
Spain	-21	-9	-9	-3	3
U.K.	-23	-7	-3	-9	-3
Japan	-29	-14	-4	-2	-8

Source OECD. '$\frac{\text{hour}}{\text{emp}}$' is average actual annual hours worked per person in employment, 'emp' is total employment, 'part' is total labor force, 'wa' is population aged 15 to 64 years, and 'pop' is total population.

We want to quantify the importance of the changes in the labor market conditions on the different evolution of hours per employee in both sides of the Atlantic. We think of the US as an economy where within skill wage inequality has increased (the variance of F has increased), the return to skill α has risen and where the unemployment probability has remained stable. We think of the EU as an economy where labor market tightness has fallen. This has reduced the probability of receiving job offers for both unemployed and employed workers ($\bar{p}_e$ and $\bar{p}_u$ have fallen). We will use the model to quantify how the different evolution in wage inequality and unemployment in the EU and the US can explain the different evolution of the number of hours worked per employee in the US and in Europe. We think of our baseline economy as representing the US and the EU in the early 70's.

5.1 U.S. in the 90's

To quantify the increase of α and ν in the US we use two statistics. First, Table 4 shows that the standard deviation of log wages after an unemployment spell has increased from around 0.50 in the 70's to around 0.75 in the 90's. Therefore, we target and increase in this standard deviation of 0.25 points. Second, we can estimate equation (13) after allowing for a change in the effect of changes in human capital on changes in wages. As

Table 9: Evolution of aggregate hours worked, Men Only (1970-2001)

	$\frac{hour}{pop}$	$\frac{hour}{emp}$	$\frac{emp}{part}$	$\frac{part}{wa}$	$\frac{wa}{pop}$
Absolute Percentage Changes					
U.S.	3	.5	-.5	-5	8
France	-24	-10	-5	-13	4
Germany	-24	-11	-7	-14	8
Spain	-23	-12	-7	-16	12
U.K.	-10	-2	-2	-10	4
Japan	-7	-9	-5	4	1
Percentage changes relative to the US					
U.S.	0	0	0	0	0
France	-27	-10.5	-4.5	-8	-4
Germany	-27	-11.5	-4.5	-11	0
Spain	-26	-12.5	-6.5	-11	4
U.K.	-13	-2.5	-6.5	-5	-4
Japan	-10	-9.5	-4.5	9	-7

Source OECD and ILO. 'emp', 'part', 'wa', and 'pop' is as in Table 8. Data are from OECD and are for men only. '$\frac{hour}{emp}$' is the average number of hours paid per week and it is from ILO. Sample period for '$\frac{hour}{emp}$' differs: for France is 1993-2002, for Germany is 1973-1995 (and refers former Federal Republic), for Japan is 1972-2001, for Spain is 1978-2001, for UK is 1986-2001, for the US is 1970-2001.

Table 5 shows, ψ_5 increases by about 6 percentage points. Therefore, we we set α equal to 0.13 in the 90's.[9] Given the new value of α, we have to increase ν up to 0.93 in order to match the increase in the dispersion of reemployment wages as documented in Table 4.

Table 10: Changes in parameters

	Low delta			High delta		
Parameter	US70	US90	EU90	US70	US90	EU90
$\bar{p}_e$	0.129	0.129	0.062	0.131	0.131	0.061
p_u	0.500	0.500	0.239	0.500	0.500	0.233
ν	0.295	0.930	0.295	0.285	0.990	0.285
α	0.075	0.130	0.075	0.075	0.130	0.075

5.2 Europe in the 90's

In Europe wage inequality has not increased much, while re-employment probabilities have fallen substantially. The evidence from the GSOEP confirms the view that inequality has

[9]Violante (2002) provides evidence that wages grow faster on the job in the 80's and in the 90's than in the 70's. This does not necessarily imply that the return to past hours worked has also increased, but it is consistent with this interpretation.

increased little in Europe. Table 4 shows no evidence that the standard deviation of reemployment wages has increased in Germany in the 90's relative to the 80's. Moreover, when we estimated equation (9) by allowing for a time varying effects of past hours worked on current wages, we did not find any evidence that the inter-temporal return to hours worked has increased in Germany (see the second panel in Table 2). This evidence is consistent with the predictions of the model.

It is well known that the rise in the EU unemployment rate is mainly explained by a fall in the exit rate from unemployment. The job separation rate, instead, has remained roughly constant, both in the US and in the EU, see OECD (1997, chap. 5) for a review of the cross-country evidence. To match the different evolution of unemployment between EU and the US, we assume that labor market tightness determines the arrival rate of job offers to employed and unemployed workers. This affects $\bar{p}_e$ and p_u. We assume that the relative effectiveness of search on the job and during employment has remained unchanged, which implies a constant value of $\bar{p}_e$ relative to p_u. Then we reduce $\bar{p}_e$ and p_u so as to match a fall in the employment rate of 7 per cent in Europe relative to the US, see Table 8.

5.3 Results

In the first column of Table 11 we report average hours relative to the trend for the benchmark economy, for the EU90 economy and for the US90 economy. When considering the low depreciation economy (top panel), we find that average hours in the US90 economy are 6.3 percent larger than in the benchmark economy, whereas average hours in the EU90 are 1.5 percent lower. In absolute terms, this means that hours worked per employee have increased by 2.8 percent in the US relative to the 70s, while they have fallen by 5 per cent in Europe. Adding up these two changes, we conclude that the joint evolution of labor market tightness and wage inequality generates a differential increase of hours between the US and the EU of 7.8 percent. This figure represents 37 percent of the actual differential of hours per employee for all workers between the US and Germany and, according to Table 9, 68 percent of the differential for male workers—which represent the natural counterpart of the calibrated economy. The results in the high depreciation economy are quantitatively similar (see bottom panel): the fall in hours in Europe is identical while the increase in hours in the US is more pronounced. Overall, the US-EU differential is 8.3 percent, which, according to Table 9, represents around 72 percent of the actual differential increase of hours worked per male worker between the US and Germany. This suggests that labor market conditions could contribute explaining a relevant proportion of the different evolution of working time in the US and Europe.

Table 11: Changes in hours worked per worker relative to trend

Economy	Average hours $\times 10^{-2}$	Diff to (1) (%)	Diff US and EU (%)
Low delta economy			
(1) Benchmark	39.5	-	-
(2) EU in the 90's	38.9	-1.5	-
(3) US in the 90's	42.0	6.3	7.8
High delta economy			
(1) Benchmark	39.5	-	-
(2) EU in the 90's	38.9	-1.5	-
(3) US in the 90's	42.2	6.8	8.3

We can also analyze the contribution of each parameter change in accounting for the widening of the EU-US differential in hours worked. In Table 12 we report the changes in hours per employee that arise when we only change the return to skill α or the dispersion of job offers, ν. The top panel deals with the low depreciation economy, the bottom panel with the high depreciation economy. When depreciation is low we find that the increase in α generates an increase in hours worked relative to trend of 1.3 percent, which represents just 4.8 percent of the overall increase in the US. The increase in ν instead accounts for an increase in average hours worked relative to trend of 5.1 percent. This represents 84 percent of the overall increase. The interaction between changes in α and changes in ν accounts for the remaining 12.5 percent of the increase. In the high depreciation economy, the increase in α accounts for 29 percent of the increase in hours per worker, whereas the increase in ν accounts for 68 percent. Overall this suggests that changes in within skill wage inequality play an important role in explaining the diverging evolution of hours worked per worker in the US and the EU.

Table 12: Decomposition of the differential

Economy	Average hours $\times 10^{-2}$	Diff to (1) (%)	Relative change (%)
Low delta economy			
(1) Benchmark	39.5	-	-
(2) $\Delta\alpha$	40.0	1.3	4.8
(3) $\Delta\nu$	41.5	5.1	84.0
(4) US90	42.0	6.3	100.0
High delta economy			
(1) Benchmark economy	39.5	-	-
(2) $\Delta\alpha$	40.3	2.0	29.4
(3) $\Delta\nu$	41.3	4.6	67.6
(4) US90	42.2	6.8	100.0

5.4 Further discussion

To evaluate the model performance, we analyze the model's ability to reproduce the sign, magnitude and time evolution of the coefficients of the equation estimated in Section 2.1. This equation provided some preliminary evidence on the evolution of the intertemporal return on hours worked. We then study some implications of our analysis for the distribution of hours worked per worker in the economy.

5.4.1 The intertemporal return

We simulate data from the model, we construct five year average of yearly wage and yearly hours worked exactly as in the PSID and we run equation (9) on model simulated data. This was the equation we used to evaluate the size and the dynamics of the intertemporal return on hours worked. When we consider the US70 and US90 economies with low depreciation rate we obtain that

$$\text{US70:} \qquad \ln w_{i,t} = cte + 0.21 \ln w_{i,t-1} - 0.53 \ln h_{i,t} + 0.49 \ln h_{i,t-1}$$
$$\text{US90:} \qquad \ln w_{i,t} = cte + 0.23 \ln w_{i,t-1} - 0.65 \ln h_{i,t} + 0.62 \ln h_{i,t-1}$$

while in the US70 and US90 economies with high depreciation economy we find that

$$\text{US70:} \qquad \ln w_{i,t} = cte + 0.20 \ln w_{i,t-1} - 0.80 \ln h_{i,t} + 0.43 \ln h_{i,t-1}$$
$$\text{US90:} \qquad \ln w_{i,t} = cte + 0.21 \ln w_{i,t-1} - 0.81 \ln h_{i,t} + 0.49 \ln h_{i,t-1}$$

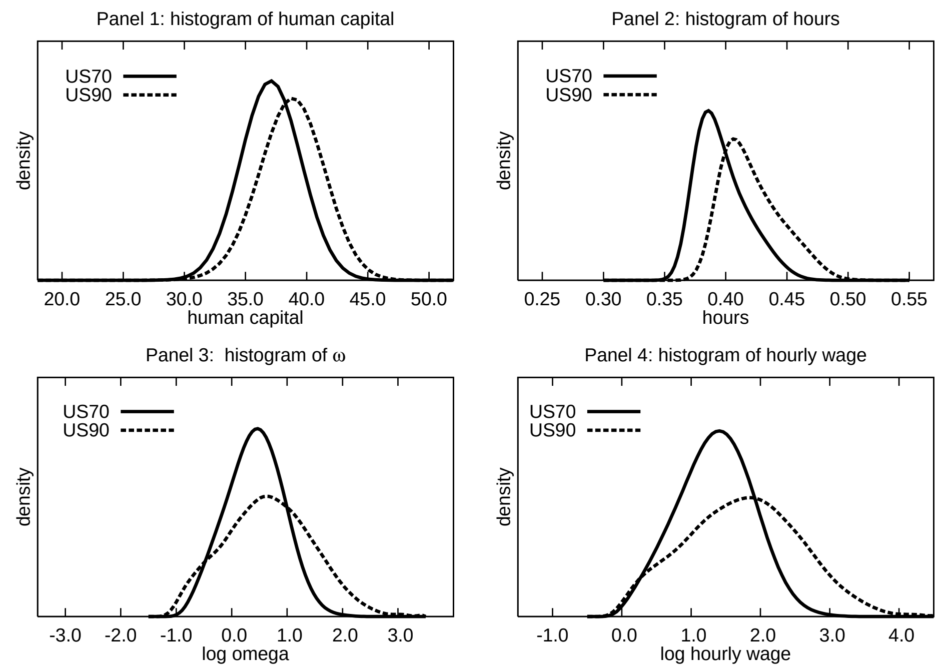
Thus the model reproduces quite accurately the dynamics of the coefficient ψ_3 obtained when estimating the equation with PSID data. Also the size of the coefficient is in line with the estimated coefficient from PSID. Only the coefficient ψ_1 that measures the serial correlation wages is lower than the estimated coefficient. The difference is less pronounced when considering the estimates with the individual fixed effects (based on the Arellano Bond estimator). We further address this issue in the next section. Notice that at no point in the calibration strategy we imposed that the calibrated economy should match the size and magnitude of the coefficient. The success of the model is remarkable.

5.4.2 The distribution of hours worked

Figures 3 and 4 further characterize the differences between the US90 and the EU90 and the benchmark economy that is intended to characterize the US in the 70s. In Figure 3 we plot the distribution of human capital (panel 1), hours worked per worker (panel 2), wage rate ω (panel 3) and hourly wage (panel 4) for the US70 and the US90 economy. In Figure 4 we deal instead with the US70 and the EU90 economies. To economize on space we present the results for the low depreciation economy only. There are two important features about the distribution of hours that are worth emphasizing. The right hand tail of the distribution of hours worked in the US increases significantly in the 90s relative to the 70s. In the economy the workers that work the longest hours are those currently employed in jobs with low ω. For these workers the return to working longer hours increase significantly in the US90 economy because of the relatively better jobs that are now available in the economy. In the EU90 economy instead the number of hours worked fall on average but the right hand tail of the distribution of hours worked remains almost unchanged. The return to working longer hour fall in Europe because of the fall in labor market tightness, but the fraction of workers working very long hours remain little affected. Workers working with very long hours typically have low ω and low human capital H. The human capital tends to fall because of the average longer spells of unemployment experienced by workers, while the probability of obtaining job offers fall because of the reduction in labor market tightness. The first effect makes hours worked increase, the second one makes them fall. In our calibrated economy the two effects balance off almost exactly and the fraction of workers working very long hours remain unchanged in Europe in the 90s relative to the 70s.

These results find empirical support in the data. (OECD 1998, chap. 5) and (OECD 2004, chap. 1) show that the fraction of workers working very long hours has changed little in Continental European. Kuhn and Lozano (2005) and Costa (2000) show instead that such fraction has increased substantially in the US over the last three decades. For example Kuhn and Lozano (2005) use data from the Current Population Survey for the US and document a sharp rise in the fraction of prime age male workers working more than 50 hours per week. They also show that the increase is more pronounced among highly educated and high wage earners, which are also the groups of workers that experienced the biggest increase in within wage inequality. The fraction of men working longer hours has also increased more in occupations and industries that also experienced a greater rise in residual wage inequality. This evidence provides support for the theory. If the increase in the US-EU differences in hours worked per worker was the result of higher marginal tax rates (as advocated by Prescott (2004)) or a greater preference towards leisure of European workers (see Blanchard (2004)), we would expect the fraction of European workers working very long hours to fall and the analogous fraction in the US to remain unchanged. For European workers working very long hours the marginal tax rate has increased the most and the marginal value of leisure is the highest.

Figure 3: Distributions: US70 vs US90



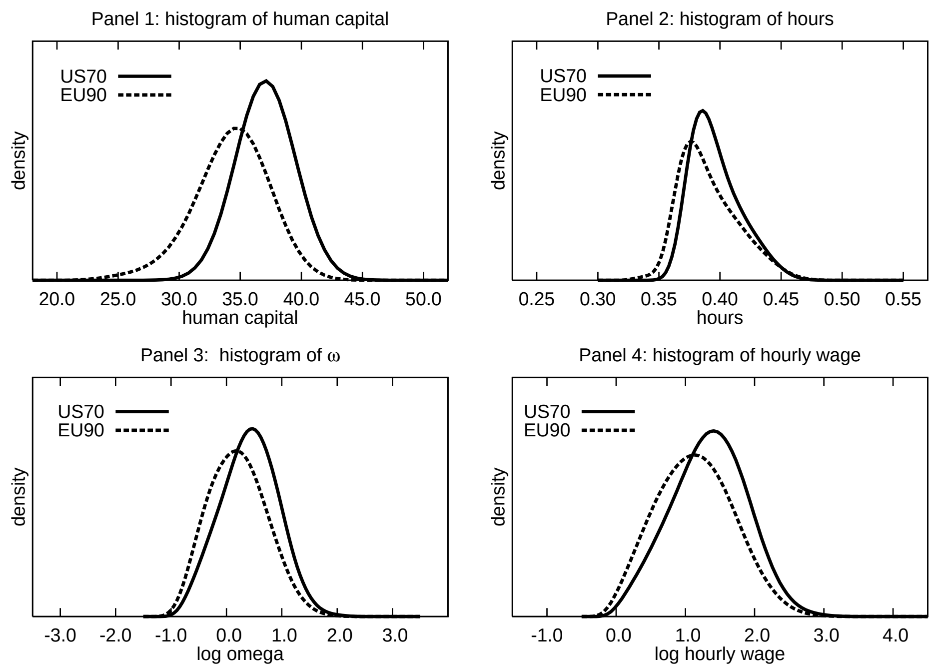
6 Extensions (incomplete)

We now analyze the robustness of our conclusions when we introduce fixed heterogeneity in the model. If fixed heterogeneity has increased this reduces the estimated increase in the dispersion of wage offers. We calibrate the increase in the dispersion in fixed heterogeneity by using the approach by Moffitt and Gottschalk (2002). We also recognize that human capital can affect the probability of unemployment. More productive workers may be less likely to enter unemployment and can find a job more easily. This can give greater incentives to work longer hours to workers in a sluggish labor market.

6.1 Endogenous unemployment probabilities (incomplete)

In the simple model studied so far the unemployment probability is not affected by the individuals' stock of human capital. In general, more able workers find jobs more easily. We now allow for human capital to affect both the job-separation probability and the reemployment probability. Allowing separation rates to decrease with human capital has several important effects: (a) it gives an extra incentive to high-wage workers to supply long hours; (b) it makes workers in economies with low reemployment probabilities willing

Figure 4: Distributions: US70 vs EU90



to work longer hours; and (c) it makes workers with high human capital more willing to supply long hours. We allow reemployment probabilities to be a function of human capital as well because this should introduce an offsetting force to the last element. And fourth, following Ljungqvist and Sargent (1998) we make unemployment income a function of human capital. Since replacement rates differ substantially between the U.S. and most European countries, this element allows us to capture a further reason for different working patterns.

There is evidence that these effects are present in the data. We estimate how past hours worked affect the fraction of time that individuals spend in unemployment. Let this fraction be denoted by ϕ. We use GSOEP and PSID to run the following regression:

$$\phi' = cte + \beta_h \ln h + \beta_\phi \phi$$

where a '' denotes the average time spent into unemployment in the next five years. We include ϕ as a control for unemployment persistence. The results from estimating the equation appear in Table 13. The results suggest that past hours worked reduces the probability of unemployment.

Table 13: Probability of unemployment

A) PSID

Hours measure:	Annual		Usual weekly	
	[1]	[2]	[1]	[2]
Log hours	-0.05	-0.05	-0.05	-0.04
	(9.08)	(7.17)	(7.17)	(4.72)

B) GSOEP

Hours measure:	Annual		Usual weekly	
	[1]	[2]	[1]	[2]
Log hours	-0.02	-0.04	-0.01	-0.02
	(4.98)	(8.81)	(3.4)	(5.76)

Note: In column [1] OLS estimates, in column [2] GLS fixed-effects estimates. t-statistics in parentheses. The dependant variable is the fraction of weeks (in PSID) or months (in GSOEP) spent in unemployment over the current five years. Hours are measured as five years averages in the previous five years. OLS regressions. All regressions include year and education dummies,potential experience (in levels and squared), and past fraction of weeks (or months) spent into unemployment.

Past hours worked can reduce the probability of unemployment by reducing the probability that a worker experiences an employment-unemployment transition, by increasing the re-employment probability in case the workers become unemployment or both. To check for this possibilities we estimate

$$\text{employment to unemployment} = cte + \beta_s \ln h$$

and

$$\text{duration of unemployment} = cte + \beta_u \ln h$$

We find that $\beta_s \sim -0.3 < 0$ and $\beta_u \sim -8.8 < 0$. This may suggest that, in a sluggish labor market workers may want to work harder to keep their job and to reduce the duration of unemployment in case the worker become unemployed.

We now analyze the effects of allowing for these effects in the model. We assume that

$$\begin{aligned} p_u(H') &= \bar{p}_u \left(1 - e^{-\gamma_u H' - (1-\gamma_u)}\right) \\ p_s(H') &= \bar{p}_s \left(1 - e^{-\gamma_s H' - (1-\gamma_s)}\right) \end{aligned}$$

and we analyze how results get modified under this alternative formulation. We calibrate γ_u and γ_s to match the previously reported values for β_s and β_u.

7 Conclusions

In a standard competitive labor market model, workers choose how many hours to work by equating the marginal utility of leisure to the marginal value of current income. The only variables that affect the choice are the current market wage and the worker's wealth. In practice individuals often decide to work longer hours to increase future as well as current income. By working longer hours they acquire greater skills and can obtain better jobs. In a market with search frictions, several features of the labor market can then influence the decision on working time. We show that a higher probability of becoming unemployed, a longer duration of unemployment, and in general a less tight labor market discourage working time. Wage inequality gives instead incentives to work longer hours.

We use data from the Panel Study of Income Dynamics (PSID), and the German Socio-Economic Panel (GSOEP), to analyze the evolution of the inter-temporal return to hours worked in the US and in Germany. In both countries we find that hours worked yield a significant inter-temporal return. Moreover, the inter-temporal return to working time has increased in the US since the 70's, while it has remained roughly constant in Germany. Preliminary evidence suggests that the different evolution of the return to skill and in within-skill wage inequality explain a substantial part of the different evolution of the return to hours worked. Overall the different evolution of the labor market conditions appears to explain between one half and two thirds of the US-EU differences in hours worked.

A Data appendix

A.1 PSID

We select all male household head who are in the age group 25-55. We exclude the SEO sample. Data start in 1968 and ends in 2001. Following is a description of the variables we use in the analysis. We include individuals for which at least 3 observations in a 5 year period are available. Table 14 contains some descriptive statistics

Labor income. total annual labor income from all jobs (applies to heads and wives). Self-employed income is split between labor and capital part and only the labor part is added.
Yearly hours. Total annual hours worked for money, from family files. It refers to all possible jobs of the worker. It includes overtime.
Weekly hours. Hours usually work per week in main job, top coded at 98 hours per week.
Tenure. Months with present employer. Since data for the Since data for the 1968-1974 period are bracketed, tenure for those years is measured by the mid point of the interval.
Race Race code for individual, from family file. We consider three dummies corresponding to white, black, or others.
Years of education Highest grade completed, 1-17 classification.
Hourly wage Labor income dived by yearly Hours divided by the GDP deflator. They are expressed in 1992 dollars.
Weeks unemployed Number of weeks spent in weeks of unemployment over the last year. In 1968 and 1969 this information is bracketed and with only one interval from 6 weeks onwards. The information is also for heads.
Weeks worked Number of weeks worked in main job.
Experience Measured as age minus six minus years of education.
Job-to-job An individual experiences a job-to job transition during the year that goes from t to $t+1$ if i) he is employed at t, ii) he is employed at $t+1$, iii) he has experienced less than two weeks in unemployment over the year, iv)he has a tenure less than 12 months at time $t+1$, and v)tenure at $t+1$ is smaller than tenure at t plus six. This last requirement try to correct for measurement error in the tenure measure.
Fraction of time in unemployment In each survey year, we have information on the number of weeks of unemployment experienced by the worker. The fraction of time in unemployment is calculated as the difference between 52 and this variable. The result is divided by 52.
Employment to unemployment An individual experiences a transition from employment to unemployment during the year that goes from t to $t+1$ if i) he is employed at t, ii) he experiences more than than two weeks in unemployment over the year.
Unemployment duration This the number of weeks in unemployment during an unemployment spell.

A.2 GSOEP

We select all male household head who are in the age group 25-55. We focus on individuals leaving in West Germany. Data start in 1985 and ends in 2002. The survey is annual up to 1997 and bi-annual thereafter. Following is a description of the variables we use in the analysis. Panel B of Table 14 contains some descriptive statistics

Labor income. Total annual labour earnings in the previous year. Labour earnings include wage and salary from all employment including training, primary and secondary jobs, and self-employment, plus income from bonuses, overtime and profit-sharing. Specifically, this is the sum of income from primary job, secondary job, self-employment, 13th month pay, 14th month pay, Christmas bonus pay, holiday bonus pay, miscellaneous bonus pay, and profit sharing income. It is obtained from Cross National-Equivalent Files.

Yearly hours. Total annual hours worked for money. Annual Work Hours of Individual in the previous year. Estimated annual hours of full-time, part-time and short-time work. It is obtained from Cross National-Equivalent Files.

Weekly hours. Original variable is "tatzeit". Actual work time per week in main job. This is the response to the question: "How many hours per week do your actual working-hours consist of including possible over-time? " The question refers to the respondent's main job.

Tenure. Original variable "erwzeit". Length Of time with current firm (in years).

Years of education Number of Years of Education completed at the time of survey. It is obtained from Cross National-Equivalent Files.

Hourly wage Labor income dived by yearly Hours divided by the CPI index. They are expressed in 2001 marks.

Months unemployed Number of months received unemployment benefits or unemployment reliefs.

Months worked In the previous Year for how many months you received wages and salary as employee? It refers to main job.

Experience Measured as age minus six minus years of education.

Job-to-job An individual experiences a job-to job transition during the year that goes from t to $t+1$ if i) he is employed at t, ii) he is employed at $t+1$, iii) he has experienced less than one month in unemployment over the year, iv) he has a tenure less than one year at time $t+1$, and v)tenure at $t+1$ is smaller than tenure at t plus 0.5. This last requirement try to correct for measurement error in the tenure measure.

Fraction of time in unemployment In each survey year, we have information on the number of months the workers received wages and salary as employee. The fraction of time in unemployment is calculated as the difference between 12 and this variable. The result is divided by 12.

Employment to unemployment An individual experiences a transition from employment to unemployment during the year that goes from t to $t+1$ if i) he is employed at t, ii) he experiences more than one month in unemployment over the year.
Unemployment duration This the number of months in unemployment during an unemployment spell.

Table 14: Descriptive statistics PSID and GSOEP

A) PSID

Year	Mean Wage	SD log-Wage	Weekly hours	Yearly hours	Yrs of schooling	Experience	Tenure
1968	15.2	.53	44.5	2126.6	11.6	22.1	103.7
1969	15.2	.52	45.5	2188.2	11.7	22.0	100.5
1970	15.5	.52	46.2	2224.8	11.9	21.4	99.6
1971	15.6	.51	45.8	2167.9	12.1	21.1	96.5
1972	15.9	.53	45.7	2150.6	12.2	20.7	89.2
1973	15.8	.53	46.0	2192.2	12.4	19.8	86.4
1974	15.9	.51	46.0	2198.5	12.5	19.3	84.3
1975	16.4	.54	46.0	2157.2	12.7	18.9	86.7
1976	15.4	.53	45.8	2115.7	12.7	18.7	91.0
1977	15.9	.54	46.1	2141.9	12.8	18.3	82.1
1978	16.1	.54	46.3	2154.5	12.8	18.0	75.0
1979	16.6	.53	45.8	2146.9	12.9	17.8	74.8
1980	16.3	.53	45.8	2152.3	12.9	17.7	77.4
1981	16.7	.56	45.1	2096.2	13.0	17.6	80.0
1982	16.3	.56	45.1	2086.8	13.0	17.6	79.0
1983	17.1	.59	44.9	2036.6	13.2	17.4	77.8
1984	16.2	.59	44.9	2061.6	13.2	17.4	81.1
1985	16.9	.61	46.0	2149.7	13.5	17.1	81.2
1986	16.3	.61	46.5	2158.9	13.5	17.2	76.9
1987	16.7	.63	46.3	2156.5	13.6	17.3	83.5
1988	18.1	.64	46.5	2185.4	13.5	17.5	81.8
1989	17.7	.64	46.7	2203.7	13.6	17.6	78.9
1990	17.8	.65	46.7	2201.8	13.6	17.9	78.9
1991	17.7	.65	46.7	2212.1	13.5	18.3	80.9
1992	18.2	.66	46.4	2169.3	13.6	18.6	81.6
1993	19.9	.67	45.3	2111.9	13.6	18.9	86.4
1994	19.3	.66	46.2	2193.1	13.6	19.4	81.3
1995	18.6	.64	46.1	2218.4	13.6	19.6	80.4
1996	19.2	.66	46.4	2248.1	13.6	19.8	81.7
1997	19.3	.65	46.1	2213.4	13.6	20.1	85.8
1999	20.5	.66	46.2	2219.3	13.6	20.5	86.9
2001	20.8	.67	46.3	2217.2	13.6	20.6	87.4

B) GSOEP

Year	Mean Wage	SD log-Wage	Weekly hours	Yearly hours	Yrs of schooling	Experience	Tenure
1984	21.4	.47	44.8	2289.0	11.8	21.8	12.6
1985	24.7	.53	44.4	2235.2	11.8	21.9	12.6
1986	24.3	.52	44.8	2258.2	11.9	22.1	12.6
1987	25.9	.52	44.5	2254.2	11.9	22.2	12.8
1988	26.7	.51	44.0	2236.2	11.9	22.6	13.1
1989	25.8	.47	44.7	2285.2	11.9	22.9	13.1
1990	25.5	.42	43.9	2275.9	12.0	23.3	13.1
1991	27.2	.45	44.0	2269.7	12.0	23.5	13.2
1992	29.1	.44	43.9	2273.5	12.1	23.6	12.8
1993	30.6	.44	43.7	2272.8	12.1	23.6	12.8
1994	31.0	.41	43.7	2267.4	12.1	24.0	13.2
1995	33.3	.47	43.8	2256.6	12.2	24.1	12.8
1996	33.4	.45	43.8	2265.3	12.2	24.2	12.1
1997	33.1	.43	44.1	2313.3	12.2	24.7	12.2
1998	36.3	.50	43.7	2262.5	12.2	27.5	13.1
1999	35.3	.50	43.8	2324.5	12.2	25.5	12.0
2000	36.7	.48	43.8	2324.7	12.3	27.1	12.3
2001	37.0	.44	44.1	2348.2	12.4	26.5	12.3
2002	38.8	.47	43.7	2334.3	12.4	27.5	12.6

Notes: The total number of observations in PSID is 65.492. The total number of observations in GSOEP is 14.270. Tenure is measured in months in PSID in years in GSOEP. Experience is measured in years.

B Computational appendix

B.1 Solving for the decision rules

We rewrite the decision problems described in section 3.1 in terms of the decision variable $h(1+\mu)^{-t}$. The two Bellman equation can be written in terms of the two stationary value functions, $W:\mathbb{R}_+^2 \rightarrow \mathbb{R}_+$ and $V:\mathbb{R}_+^2 \rightarrow \mathbb{R}_+$, that describe the value of a job and the value of unemployment. Let's define $\mathcal{V}$ as the space of the real-valued continuous functions on the $\mathbb{R}_+^2$ domain. Then, we can see see the two Bellman equations as an operator $T:\mathcal{V}\times\mathcal{V}\rightarrow\mathcal{V}\times\mathcal{V}$ and the pair of value functions $\{W,V\}$ as a fixed point of this operator. We will look for this fixed point by a successive approximations method: we guess an initial pair $\{W_0,V_0\}\in\mathcal{V}\times\mathcal{V}$, apply the operator T, obtain a new pair $\{W_1,V_1\}$, apply the operator T and so on until the distance between two successive pairs is small enough. However, to find this fixed point by use of a computer, we first need to define an analogous approximated problem.

We start by a normalization. Since new offers $\omega\in\mathbb{R}_+$ are distributed log-normally, we rewrite the state space such that new offers follow a standard normal distribution. The standardized offer $z\in\mathbb{R}$ is given by,

$$z=\frac{\log\omega+\frac{\nu}{2}}{\sqrt{\nu}} \tag{14}$$

and we can replace the distribution F by Φ, the *cdf* of the $N(0,1)$ distribution. Then, we discretize the state space such that $H\in\hat{H}\equiv\{H_1,H_2,\dots,H_{N_H}\}$, $\hat{B}\equiv\{b_1,b_2,\dots,b_{N_b}\}$ and $z\in\hat{Z}\equiv\{z_1,z_2,\dots,z_{N_Z}\}$.[10] Then, we look for the approximated functions $\hat{W}:\hat{Z}\times\hat{H}\rightarrow\mathbb{R}_+$ and $\hat{V}:\hat{B}\times\hat{H}\rightarrow\mathbb{R}_+$ that define the value of employment and unemployment. The last step to characterize the approximated problem is to define the appropriate approximated operator $\hat{T}$, that is to say, we need to redefine equations (10) and (11).

The first thing to note is that we may need to evaluate W and V at points outside the grids. In this case we will just interpolate. In order to solve the problem of the unemployed we differentiate the Bellman equation (11) with respect to the reservation wage. This gives us a simple first order condition,

$$V\left(b,(1-\delta_u)H\right)-W\left(\exp\left(z_r\sqrt{\nu}-\frac{\nu}{2}\right),(1-\delta_u)H\right)=0$$

that we solve for the reservation offer z_r using Brent's method at all points in the set $\hat{B}\times\hat{H}$. This gives us the approximated decision rule $\hat{g}^{z_r}:\hat{B}\times\hat{H}\rightarrow\mathbb{R}_+$. To solve the problem of the employed workers we impose h to belong to the discrete set $\hat{h}\equiv\{h_1,h_2,\dots,h_{N_h}\}$.[11] Then, $\forall\{z,H\}\in\hat{Z}\times\hat{H}$, we just search for the $h\in\hat{h}$ that maximizes the Bellman equation. This gives

[10] We choose $N_H=64$, $N_B=2$ and $N_Z=45$. Note that the domain of offers z is the real line and instead $\hat{Z}$ is bounded. We choose $z_1=-3.5$ and $z_{N_\omega}=3.5$ and therefore we only lose about 0.046% of the probability distribution.

[11] We work with $N_h=3000$

us an approximated decision rule $\hat{g}^h : \hat{Z} \times \hat{H} \rightarrow \mathbb{R}_+$.

To update the value functions we need to compute integrals of the type,

$$G(z) = \int_z^{\infty} f(s)\,\phi(s)\,ds \tag{15}$$

where $\phi(\cdot)$ is the density function of the $N(0,1)$ distribution and $f(\cdot)$ is a function of z that will be described by a vector on $\mathbb{R}^{N_z}$. One approach is to use a quadrature method over this integral. The problem is that since we will need to compute these integrals $\forall z \in \mathbb{R}$ the level of accuracy of the solutions will differ substantially for different values of z. Besides, using quadrature methods directly to approximate expression (15) might be too expensive in computer time. There are two reasons for this. First, because it would require to evaluate the integral at many points outside $\hat{Z}$, which requires interpolating the function $f(\cdot)$; and second because it would also require to evaluate $\phi(\cdot)$ at different points in $\mathbb{R}$ for each approximation. Therefore, we will follow a different approach. First, let's define $\hat{\Phi}(z_1) = 0$. Then, $\forall z_i \in \{z_2, z_3, \ldots, z_{N_z}\}$ we define $\hat{\Phi}(z_i)$ as

$$\hat{\Phi}(z_i) = \hat{\Phi}(z_{i-1}) + \int_{z_{i-1}}^{z_i} \phi(z)\,dz$$

where the integral on the right hand side is approximated by Newton-Coates quadrature. Then, $\forall z_i \in \hat{Z}$ we approximate expression (15) as

$$G(z_i) = \int_{z_i}^{\infty} f(s)\,\phi(s)\,ds \simeq \sum_{j=i}^{N_z-1} \frac{f(z_j) + f(z_{j+1})}{2} \left[\hat{\Phi}(z_{j+1}) - \hat{\Phi}(z_j)\right] \tag{16}$$

Since $\hat{\Phi}(z_j)$ can be tabulated $\forall z_j \in \hat{Z}$, all the expectations are very fast to compute. In addition we do not need to evaluate $f(z)$ outside the grid $\hat{Z}$. Finally, to compute $G(z)$ for $z \notin \hat{Z}$ we just interpolate.

B.2 Finding the aggregate distribution

In order to find the stationary distribution X we work with a finite sample of 10,000 individuals. We simulate 725 periods and drop the first 600. The remaining 125 periods gives us 10 years of monthly data for our model economy.

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