A Life-Cycle Model of Trans-Atlantic Employment Experiences

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Abstract

To understand trans-Atlantic employment experiences since World War II, we build an overlapping generations model with two types of workers whose different skill acquisition technologies affect their career decisions. Search frictions affect short-run employment outcomes. The model focuses on labor supply responses near beginnings and ends of lives and on whether unemployment and early retirements are financed by personal savings or public benefit programs. Higher minimum wages in Europe explain why youth unemployment has risen more there than in the U.S. Higher risks of human capital depreciation after involuntary job destructions cause long-term unemployment in Europe, mostly among older workers, but leave U.S. unemployment unaffected. Increased probabilities of skill losses after involuntary job separation interact with workers' subsequent decisions to invest in human capital in ways that generate the age-dependent increases in autocovariances of income shocks observed by Moffitt and Gottschalk (1995).

Key words: Heterogeneity, search frictions, experience, human capital, disutility of work, aging, job tenure, unemployment duration, hazard rate, early retirement, earnings volatility, autocovariance of income shocks, unemployment benefits, job protection, minimum wage.

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1 Introduction

Before the 1970s, unemployment rates were significantly lower in Europe than in the U.S., but after the 1970s, Europe suffered persistently higher unemployment than the U.S. These aggregate outcomes conceal important differences over life cycles of European and American workers. Figure 1 displays the unemployment rate and the employment-to-population ratio at different ages for men in France and the U.S. in 1970 and 2004.[1] We include the employment-to-population ratio because many workers who collect government provided disability insurance and early retirement payments are probably unemployed rather than unable to work (see OECD (2003, chap. 4)). Most macro-labor analyses of trans-Atlantic employment experiences in the tradition of matching models (e.g., Mortensen and Pissarides (1999)) and also in frictionless representative household models (e.g., Prescott (2005)) ignore life cycle dynamics.

This paper constructs a heterogeneous-agent life-cycle model that fits cross-time and cross-continent differences in employment by age while preserving a string of quantitative successes achieved by earlier macro-labor studies. Our model makes contact with data on life-cycle profiles of asset holdings, consumption, and earnings as well as age-dependent flows into and out of unemployment.[2] It does this while incorporating mechanisms from earlier work by Mortensen and Pissarides (1999) and Ljungqvist and Sargent (2008) that portray situations in which government-imposed layoff costs that suppress frictional unemployment can offset some of the unemployment increases caused by generous unemployment benefits.

To explain trans-Atlantic employment outcomes, this paper extends Ljungqvist and Sargent's (1998, 2008) studies of the consequences of microeconomic 'turbulence'. Bertola and Ichino (1995) and Ljungqvist and Sargent (1998) argued that the outbreak of high European unemployment around 1980 was connected to Gottschalk and Moffitt's (1994) finding that the instability of earnings of U.S. workers increased between the 1970s and the 1980s. Bertola and Ichino (1995) interpreted greater earnings instability as reflecting more volatile local demand shocks and showed how a rigid wage and high layoff costs in Europe would lead to higher unemployment in a model with homogeneous workers. In contrast, Ljungqvist and Sargent (1998, 2008) imputed some increased earnings variability to shocks to workers'

[1]See also Rogerson (2006) who reports the employment-to-population ratio for both men and women in the U.S. and several European countries in 2003. Except for Italy with its lower female labor market participation, the same picture emerges as in our figure 1 where the prime-age European population of age 30 through 50 has very similar participation rates to those of the U.S. population.

[2]For two related life-cycle models of unemployment, see Hairault et al. (2010) and Low et al. (2010) who attribute elevated old-age unemployment to benefit programs that are available only to older workers.

human capital and showed how generous unemployment benefits in Europe would generate high long-term unemployment among workers who had lost human capital after their most recent layoff. Instead of Ljungqvist and Sargent's learning-by-doing technology, the present analysis includes Ben-Porath's (1967) human capital acquisition technology, and shows how turbulence generates age-dependent increases in autocovariances of income shocks like those documented by Moffitt and Gottschalk (1995).

Our models of economies on the two sides of the Atlantic ocean share common demographics, preferences, and technologies for production, job market search, and human capital acquisition. Of these primitives, we assume that only the human capital acquisition technology changed over time and that it changed in the same way on both the two sides of the Atlantic ocean, in particular, that it deteriorated between what we call tranquil times (before the 1970s) and turbulent times (after the 1970s) in the sense that there was an increased risk of losing more human capital at times of involuntary job destruction. This is our notion of an increase in turbulence. We compute distinct steady states in tranquil and turbulent times. Differences in government policy are the only causes of differences in outcomes across the two continents in these steady states. We hold taxation, social security, unemployment insurance, and job protection policies constant *across time*, but make them differ systematically *across continents*: most importantly, in Europe, unemployment insurance is of longer duration and job protection is stronger. The minimum wage is assumed never to bind in the U.S. and not in Europe prior to the 1970s. But we make the European minimum wage binding after the 1970s for workers with low education and experience.

Our primitives rest on two pillars that support 'time-averaging' models: (1) indivisibilities in labor supply, and (2) time separable preferences that express a distaste for volatile consumption. By dropping the employment lotteries and complete markets that had been a microfoundation for macroeconomic models that determined a fraction of the population that was randomly assigned to work each period (see Prescott (2005)), time-averaging models eliminate an aspect of macro models that labor economists disliked. Time-averaging models replace those fractions of people randomly assigned to work with fractions of lives that individual workers choose to work.[3] At interior solutions for career length, a time-averaging

[3] Abstracting from productivity shocks and human capital in an indivisible-labor complete-market model in continuous time, Ljungqvist and Sargent (2006) showed that, holding the workers' preferences fixed, the same labor supply elasticity would emerge if the employment lotteries and complete markets were withdrawn and instead individual workers were forced to confront the indivisible labor choice by choosing fractions of their lifetimes to work while trading a single risk-free asset to smooth their consumption over time. As a discussant, Prescott (2006a) welcomed the abandonment of employment lotteries, and proceeded to revise his earlier Nobel lecture (Prescott (2005)) by adding a new section on "The Life Cycle and Labor Indivisibility"

model like ours would exhibit the same high labor supply elasticity at the extensive margin that an employment lotteries model would at an employment-population ratio less than one. The reason that labor supply turns out *not* to be highly elastic in our model in tranquil times, either in the U.S. or in Europe, is that our calibration puts workers at a corner solution for career length that is generated by an official retirement age.[4] That corner solution explains why in tranquil times our model generates similar employment outcomes in Europe and the U.S. despite higher taxes and more generous benefits in Europe.

Ljungqvist and Sargent (2014, sec. 4) describe conditions that in a time-averaging model cause workers to shorten their careers by privately financing early retirement after a permanent negative earnings shocks. In the model of this paper, human capital losses in turbulent times conclude careers in Europe because of the incentives provided by publicly financed long-term unemployment and early retirement programs that are available in Europe but not in the U.S. The conjunction of increased turbulence and the outbreak of high European unemployment enable us to identify and calibrate a key parameter in our framework – the disutility of work.

The remainder of this paper is organized as follows. Section 2 previews key forces in the model and how we use them to calibrate parameters. Section 3 describes the model environment in detail. Bellman equations are specified in section 4. Section 5 explains the calibration of the model, and section 6 reports on the outcomes of the analysis. Concluding remarks are offered in section 7.

2 Key forces and calibration strategy

The following two subsections describe sources of workers' heterogeneous lifetime labor market experiences and how a decomposition of the parameter space guides our calibration of the model via simulated moments. These descriptions identify interactions among forces that allow the model to capture trans-Atlantic employment experiences after World War II and also yield auxiliary implications that line up well with observations on lifetime consumption and asset profiles, the turnover of workers and jobs, and the changing dynamics of individual earnings data.

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in a second edition (Prescott (2006b)), in which he extends the Ljungqvist and Sargent (2006) analysis to include a particular intensive margin in workers' labor supply.

[4]See Ljungqvist and Sargent (2014, sec. 6) for a time-averaging analysis of implicit tax wedges in pension systems that can cause heterogeneous agents to stop working at the same official retirement age.

2.1 Heterogeneities

A constant population consists of overlapping generations of heterogeneously situated workers who randomly survive from period to period and live at most T periods. The presence of an indivisibility makes a person work either full time or not at all in a given period. As in the Lucas and Prescott (1974) island model, a worker must search for 'the labor market'. Once there, he earns a competitively determined wage per unit of the effective labor that he had acquired by investing in human capital, but subject to a transitory earnings shock. When not working, a person either enjoys leisure full time or searches for the labor market at a disutility-causing intensity of his choice. A worker passes through three phases: (1) a phase of youthful inexperience characterized by an environment with a high job destruction rate and frequent changes of jobs at productivities drawn from a McCall (1970) style offer distribution; (2) a mature phase as an experienced worker who confronts a lower rate of job destruction than he had while he was "inexperienced" and who now has access to a human capital acquisition technology in the style of Ben-Porath (1967); and (3) a phase of mandatory retirement that starts at age $T^n + 1 < T$. The worker can choose not to work during phases (1) and (2). If he withdraws from the labor market permanently, we say that he retires before the mandatory retirement age. There are two ways that workers who are unemployed and workers who retire early support themselves. Workers save by acquiring a single risk-free financial asset. Accumulations of this asset are one way to finance consumption during retirement and other times when the worker is not supplying labor or is suffering transitory negative earnings shock while employed. Payments from the government in the form of unemployment compensation and social security retirement benefits are another source of funds. Workers are heterogeneous. *Ex ante*, there are two types of workers, high and low, that we think of as high school only and college graduates, respectively. They are distinguished by the probability distributions of potential productivities that they face and also by the parameters of their Ben-Porath human capital acquisition technologies. Workers' decisions to acquire human capital in the face of these technologies contribute realistic differences in profiles of labor earnings and financial assets across our two types of workers. *Ex post* heterogeneity is generated by luck in drawing random numbers that determine (1) job search outcomes, (2) times taken to become an experienced worker, (3) transitory earnings shocks while employed, (4) job destruction, and (5) extraordinary human capital depreciation at times of involuntary job loss.

One-worker firms are randomly paired with workers in the labor market in each period. All active firms pay the competitively determined wage per efficiency unit of labor and rent capital. Idiosyncratic productivities that follow a Markov process make firms heterogeneous *ex post*. A firm can be created by incurring a startup cost. Firms exit because they receive exogenous destruction shocks or because their productivities fall below an optimal reservation productivity. By imposing a job destruction tax, the government influences the reservation productivity and through it the layoff rate and productivity distribution of active firms.

2.2 Calibration with simulated moments

We first parameterize government policies: tax rates on labor and capital, unemployment insurance, social security systems, minimum wages and layoff costs. We base our parameterization on official statistics and commonly accepted estimates. When the literature reveals disagreements about magnitudes, we err on the conservative side by understating policy differences across continents. For example, while assuming no layoff tax in the U.S., we calibrate a European layoff tax at only three months of low-type workers' average earnings.

For given government policies, we find that outcomes change smoothly in response to perturbations of all parameters except one that measures the disutility of work. Except for that disutility parameter, other parameters mainly affect one equilibrium outcome while having only minor effects on other outcomes. This structure of the model guides our approach to calibrating it. Fixing the disutility that a worker suffers when supplying labor, we sequentially iterate over parameters that determine: (i) agents' decisions to consume, supply labor, and accumulate financial assets and human capital; (ii) firms' decisions to hire and fire workers. We eventually calibrate the disutility of work in a third stage.

We initialize our calibration procedure with a value for the disutility of work. It must be set low enough that in the absence of human capital losses, in both Europe and the U.S. workers do not want to retire before the mandatory retirement age.

In the first stage, we treat firms' layoff rates as if they were fixed, deferring fitting those layoff rates to the second stage. Given that caveat, we calibrate the model of the U.S. in tranquil times. The subjective discount rate and parameters of the job search and human capital technologies and of the layoff rate are determined by targeting observations on durations of unemployment spells, earnings profiles, asset holdings, and numbers of jobs held over a lifetime. (The aggregate unemployment rate is a function of the average duration of unemployment and the inflow into unemployment, as implied by rates of job churning.) For Europe, we import the technology parameters and the subjective discount rate from the calibration of the U.S. model; but not the layoff rate. Unemployment was lower in

Europe than in the U.S. during what we identify as the tranquil decades of the 1950's and 1960's, a difference mechanically accounted for by a lower inflow rate into unemployment in Europe along with similar average durations of unemployment in Europe and the U.S. (See Layard et al. (1991)). For Europe, our calibration target is a layoff rate that generates a tranquil-times unemployment rate 1.5 percentage points lower than in the U.S.

In the second stage, the distribution of human capital for workers who have found 'the labor market' from the first calibration stage together with any government imposed layoff tax and the idiosyncratic productivity process determine firms' reservation productivity that in turn implies a layoff rate for that economy. Since our first calibration stage has already identified the U.S. and European layoff rates to be fit, we use those two layoff rates as calibration targets when parameterizing a common idiosyncratic productivity process for firms in both the U.S. and Europe. Given that calibrated productivity process, a European layoff tax equal to three months of low-type workers' average earnings explains the suppressed layoff rate in Europe which in turn implies a European unemployment rate that is 1.5 percentage points lower than the unemployment rate in the U.S. with its zero layoff tax.

In the third stage, we jointly calibrate the value of the disutility of work and the stochastic process for shocks to human capital of displaced workers in turbulent times. Here the calibration targets are, first, to capture that European unemployment more than doubles in turbulent times, and, second, to reproduce Gottschalk and Moffitt's (1994) observation of increased earnings volatility in the U.S. On the one hand, too low a disutility of work could generate such a high European unemployment rate only if the shocks to earnings were much larger than observed. On the other hand, too high a disutility of work would make European unemployment respond too much to human capital losses, meaning that we could fit the dramatic increase of European unemployment only by assuming counterfactually small increases in shocks to earnings.

3 Environment

The gross interest rate $1 + r$ is exogenous. As described in section 5, one key steady state is calibrated so that the people in the model hold half of the economy's physical capital.

3.1 Worker activities, search and human capital technology

In each period, there arrives a new cohort of agents who are alive for at most T periods. Agents of age $t < T$ face a probability m_t of surviving until next period. Conditional on surviving, an agent is of working age during her first $T^n < T$ periods of life but cannot work during her remaining $T - T^n$ periods. $T^n + 1$ is a mandatory retirement age. A worker can choose to retire earlier. An unemployed agent of working age has access to a search technology like one posited by Alvarez and Veracierto (2001). By expending a search effort $s \in [0, 1]$, an agent finds 'the' centralized labor market next period with probability $S(s)$ if she is experienced, and with probability $\tilde{S}(s)$ if she is inexperienced. All workers go through an initial phase of 'inexperience' before entering a later phase of 'experience'. The type of job a worker encounters depends on whether she is in the first or second phase of her labor market career.

There is *ex ante* heterogeneity because two types of workers $i = H, L$ are differentiated according to (1) when they are inexperienced, the probability distribution $G_i(\hat{n})$ of effective units of labor from which they draw jobs, and (2) when they are experienced, an initial level $h_{o,i}$ and the parameters of a skill acquisition stochastic matrix $H_i^n(h, \bar{h}; \ell)$ that governs stochastic transitions from human capital h to human capital $\bar{h}$. To operate that skill acquisition technology, an experienced worker needs to be employed.

An inexperienced agent of type i who finds the labor market draws a job offer to supply $\hat{n}$ effective units of labor from a probability distribution $G_i(\hat{n})$. If the offer is accepted, effective units of labor remain constant as long as the agent retains the job and does not become experienced. For the sake of brevity, we refer to it as a worker's 'job' but, as will become clear in section 3.3, it would be more accurate to call it a worker's 'spell in the labor market'. At the end of a period, after working but before workers have chosen their consumption rates, nature separates inexperienced workers from jobs with probability $\tilde{\lambda}$, and firms choose to destroy other jobs with probability q. If a job survives, an inexperienced agent faces a probability π that she becomes experienced and enters the second phase of her career. Next, agents whose jobs have not been destroyed decide whether to keep their jobs or to quit and search for new ones next period. The effective units of labor supplied by an agent who just became experienced and did not quit are $\hat{n}(h_{o,i}, l)$, where $h_{o,i}$ is the initial human capital of an agent of type i, that will remain with her for the rest of her working life, and l is the time that the agent devotes to acquiring additional human capital.[5]

[5]The phase of 'inexperience' captures the job churning by young workers observed by Neal (1999) who formulated a search model in which a worker's productivity is the sum of two components – a career match

At the end of a period after working but before consumption decisions are made, nature destroys jobs held by experienced agents with probability $\lambda \leq \tilde{\lambda}$ and firms destroy more with probability q.[6] If a job survives and the worker does not quit, an employed experienced agent chooses how much time $l \in [0,1]$ to spend on human capital acquisition next period. The agent's effective units of labor supply, $\hat{n}(h,l) = h(1-l)$, declines in l. By allocating l units of time in a period, she acquires a type-dependent probability $H_i^n(h,\bar{h};l)$ that her human capital at the end of the period is $\bar{h}$. But before it is used in production, with probability λ, an employed agent experiences a job destruction event chosen by nature, and then her end-of-period human capital is subject to yet another transition probability $H_i^\lambda(\bar{h},h')$.

When supplying $\hat{n}$ effective units of labor, a worker is subject to an i.i.d. earnings shock θ with probability distribution $\Theta(\theta)$ that makes her labor supply become $n = \theta\,\hat{n}$ in that period, which we call her efficiency units of labor. A worker's decision to supply labor is taken before θ is realized.

3.2 Preferences

We assume that preferences are separable between consumption and leisure,

$$E_0 \sum_{t=0}^{T} \beta^t \big[\log c_t - B_t\big], \qquad \text{with } B_t \in \{B^u(s),\, B\}, \tag{1}$$

where we have adopted a logarithmic form that would be consistent with balanced growth if there were technological progress. The disutility of effort includes both a disutility of search

and a job match. At the beginning of a period, a worker can draw new values of both components, or she can retain her career and draw only a new job. The optimal career-job strategy has a worker focus on finding a suitable career before searching for an ideal job. While this theory generates churning, it does not explain lengths of employment spells during that process because values of careers and jobs are known as soon as they are drawn. One way to embellish the environment would be to incorporate learning like Pries and Rogerson (2005). For tractability, Pries and Rogerson assume that successive observations of a worker's output is the sum of a true underlying match quality and a uniformly distributed i.i.d. random noise, so that learning takes a simple "all-or-nothing" form. Unfortunately, that tractability comes at the price of an unrealistically large variation in output. For example, in Pries and Rogerson's preferred parameterization of two possible match qualities, bad and good, the corresponding ranges of realized outputs, not reported in their paper, are $[-2.46, 4.46]$ and $[-1.56, 5.36]$, respectively, where realizations in the disjoint set perfectly reveal the true match quality and others are uninformative. Given the problematic nature of these models for quantitative analysis, we opted for our hard-wired representation of the phase of inexperience. We expect that similar outcomes would emerge from a more fully specified model with features drawn from Neal (1999) and Pries and Rogerson (2005).

[6] Compared to experienced workers, we subject inexperienced workers to an additional risk of job separation, $(\tilde{\lambda} - \lambda) \geq 0$, in order to induce additional job churning in the initial phase of inexperience.

when unemployed $B^u(s)$ that is increasing in s; and a disutility of work B. The disutility of work has no intensive margin since our agents can work either full time or not at all.

3.3 Production technology

The production technology is the same as in Ljungqvist and Sargent (2007) except that we alter the process that randomly matches workers with firms. Ljungqvist and Sargent (2007) assumed that jobs newly created by firms are matched randomly with workers who have just found the centralized labor market, but that ongoing firm-worker matches continue until they are broken by a worker's either quitting or dying or by a firm's decision to end a job. To facilitate analysis, in this paper we assume that *all* pre-existing 'job sites', including both newly created and continuing ones, are randomly re-matched with workers who find themselves in the centralized labor market. A process randomly matches a firm job site with someone drawn from the pool of workers present in the centralized labor market. The firm pays that randomly drawn worker a competitively determined wage times that worker's particular supply of efficiency units of labor. There are no 'jobs' in the sense of long-term relationships between particular firms and particular workers. Instead, to a worker a 'job' refers to her current spell in the centralized labor market, while to a firm a 'job' is an ongoing profitable employment opportunity that is occupied over time by different people who vary randomly in both their skill and experience levels.

We have designed our environment to confront firms with interesting job creation and destruction decisions, and workers with interesting search and quitting decisions, while also allowing an equilibrium wage to equate an aggregate demand with an aggregate supply of efficiency units of labor. Our specification is in the spirit of Lucas and Prescott (1974) and Alvarez and Veracierto (2001), who invented manageable environments in which workers search but a unique wage rate per efficiency unit of labor is nevertheless determined competitively.

Incurring a startup cost μ allows a firm to create a job next period with productivity level $z = z_{\text{initial}}$. The productivity level after that is generated by a Markov transition kernel $Z(z, z')$. At the end of a period, nature exogenously destroys jobs with probability λ; then firms can choose to terminate other jobs.

A firm's production function is

$$F(z, k, n) = z\, k^{\alpha} n^{1-\alpha}, \qquad \text{with } \alpha \in (0, 1), \tag{2}$$

where z is a job-specific productivity level, k is physical capital that depreciates at the rate δ, and n is efficiency units of labor supplied by the worker filling the job.

The timing of events is as follows. At the end of a period, a fraction λ of all jobs is randomly and exogenously destroyed. Next, firms with surviving jobs observe productivity levels and choose whether to terminate jobs or to produce at the new productivity level next period. This decision is taken before knowing the identity of the worker who will fill a particular job next period. That means that all firms choose the same reservation productivity level $\bar{z}$ and that the population of firms terminates a fraction q of jobs that survived after the exogenous probability λ termination shock. Next period, all remaining jobs and newly created jobs are randomly assigned to workers present in the centralized labor market. Firms observe their workers' efficiency units of labor and then rent amounts of capital that maximize profits. Workers receive a competitively determined wage rate w per efficiency unit of labor, which ensures that all workers in the central labor market are employed and that newly created jobs expect to break even.

Firms and workers are both affected by the exogenous job destruction rate λ. At the end of a period, a fraction λ of all firms' jobs are randomly destroyed, and a fraction λ of all employed workers are randomly separated from the centralized labor market. Similarly, firms' endogenous destruction of jobs at a rate q generates that same fraction of forced separations from the centralized labor market among employed workers. In contrast, workers who quit have no direct impacts on firms since firms' jobs are randomly matched in each period with remaining workers and newcomers in the centralized labor market. Similarly the additional exogenous separation rate among inexperienced workers, $(\tilde{\lambda} - \lambda) \geq 0$, has no direct consequences for firms.

3.4 Government policies

The government's labor market policy consists of three programs. First, workers who are exogenously or endogenously laid off by firms are entitled to unemployment benefits for $d_{\max}$ periods. During that entitlement period, a function $\Gamma(e)$ maps lost earnings e, excluding any transitory earnings shock θ, into benefits that are paid until the worker either finds a new job or retires. Second, firms pay a job destruction tax Ω for each job that they choose to terminate. Third, the government imposes a 'minimum wage', or more precisely, a minimum earnings level $e_{\min}$, excluding any transitory earnings shock θ.

The government taxes labor earnings including unemployment benefits at a rate τ_n and interest earnings at a rate τ_k. Labor earnings are also subject to the payroll (social security) tax at rate τ_p. Social security benefits of ϵ are paid to retirees who have reached the mandatory retirement age $T^n + 1$. All accidental bequests are collected by the government. The difference between revenues from taxation and accidental bequests, and payments for unemployment benefits and social security benefits is spent on public consumption X.[7]

4 Bellman equations

Tables 1 and 2 show states, decisions, and value functions for several classes of agents. An inexperienced worker bears a tilde on her value function and has state a, γ, d, t when she is unemployed and a, $\hat{n}$, t when she is employed, where a denotes her assets, γ her past-earnings-related unemployment compensation, d her elapsed duration of unemployment (this tracks UI benefits eligibility of limited duration), t her age, and $\hat{n}$ her effective units of labor. Value functions of experienced workers bear no tilde's and have state a, h, t when employed and a, h, γ, d, t when unemployed, where h denotes a worker's human capital level. Agents of age $t > T^n$ are retired, and have state a, t.

For notational simplicity, let $A^o(x)$, $A^n(x, n)$ and $A^u(x, \gamma)$ denote assets, including a current period's net-of-tax income, of a retired agent, an employed agent and an unemployed agent, respectively. These assets can be consumed or saved in the current period. They are functions of an agent's savings x last period, an employed agent's labor supply in efficiency units n, and an unemployed agent's unemployment benefits γ:

$$
\begin{aligned}
A^o(x) &= [1 + (1 - \tau_k)r]\, x + \epsilon\,, & (3)\\
A^n(x, n) &= [1 + (1 - \tau_k)r]\, x + (1 - \tau_n - \tau_p)\, w\, n\,, & (4)\\
A^u(x, \gamma) &= [1 + (1 - \tau_k)r]\, x + (1 - \tau_n)\, \gamma\,. & (5)
\end{aligned}
$$

4.1 Retired people

The value function for a retired agent is

$$
\begin{aligned}
V^o(a, t) &= \max_c \left\{ \log(c) + \beta m_t V^o(A^o(a - c), t + 1) \right\}\,, & (6)\\
\text{subject to} \quad & c \in [0, a]\,.
\end{aligned}
$$

[7]Our calibration strategy is to match tax rates and benefits and to let X be a residual. Hence, the computation of an equilibrium involves no loop to impose the government budget constraint.

Policy function $c^o(a,t)$ describes the optimal level of consumption.

4.2 Experienced workers

The value function of an experienced agent of type $i = H, L$ who has accepted an employment opportunity for next period is

$$\begin{aligned} V_i^n(a,h,t) \;\; = \;\; & \max_{c,l'} \Bigg\{ \log(c) + \beta m_t \Bigg[-B^n + \sum_{\theta'} \Theta(\theta') \sum_{\bar{h}} H_i^n(h,\bar{h};l') \\ & \cdot \Bigg(\lambda \sum_{h'} H_i^{\lambda}(\bar{h},h') V_i^u(A^n(a-c,\theta'\hat{n}(h,l')), h', \Gamma(w\hat{n}(h,l')), 1, t+1) \\ & + (1-\lambda) q V_i^u\big(A^n(a-c,\theta'\hat{n}(h,l')), \bar{h}, \Gamma(w\hat{n}(h,l')), 1, t+1\big) \\ & + (1-\lambda)(1-q) \max\Big\{ V_i^n\big(A^n(a-c,\theta'\hat{n}(h,l')), \bar{h}, t+1\big) \, , \\ & \qquad V_i^u\big(A^n(a-c,\theta'\hat{n}(h,l')), \bar{h}, 0, 1, t+1\big) \Big\} \Bigg) \Bigg] \Bigg\} , \end{aligned} \tag{7}$$

$$\text{subject to} \qquad c \in [0,a] \, , \;\; l' \in [0, \, 1 - e_{\min}/(wh)] \, .$$

Policy functions $c_i^n(a,h,t)$ and $l_i(a,h,t)$ give optimal levels of consumption in the current period, and time spent on human capital accumulation in the next period, respectively.

The value function for an experienced unemployed agent is

$$\begin{aligned} V_i^u(a,h,\gamma,d,t) \;\; = \;\; & \max_{c,s'} \Bigg\{ \log(c) + \beta m_t \Bigg[-B^u(s') \\ & S(s') \max\Big\{ V_i^n(A^u(a-c,\gamma'), h, t+1) \, , \\ & \qquad V_i^u(A^u(a-c,\gamma'), h, \gamma', d+1, t+1) \Big\} \\ & + \big[1 - S(s')\big] V_i^u(A^u(a-c,\gamma'), h, \gamma', d+1, t+1) \Bigg) \Bigg] \end{aligned} \tag{8}$$

$$\text{subject to} \qquad c \in [0,a] \, , \;\; s' \in [0,1] \, , \;\; \gamma' = \begin{cases} \gamma, & \text{if } d < d_{\max} \, ; \\ 0, & \text{if } d \geq d_{\max} \, . \end{cases}$$

Policy functions $c_i^u(a,h,\gamma,d,t)$ and $s_i(a,h,\gamma,d,t)$ give optimal levels of consumption in the current period, and time spent on job search in the next period, respectively.

In period $T^n - 1$, the agent would optimally set $l' = 0$ if employed and $s' = 0$ if unemployed, and all the continuation value functions in Bellman equations (7) and (8) would be replaced by $V^o(A^n(a-c,\theta'\hat{n}(h,l')),t+1)$ and $V^o(A^u(a-c,\gamma'),t+1)$, respectively.

4.3 Inexperienced workers

The value function of an inexperienced type i agent who has accepted an employment opportunity for next period is

$$
\begin{aligned}
\tilde{V}_i^n(a,\hat{n},t) \;=\; & \max_c \Bigg\{ \log(c) + \beta m_t \Bigg[-B^n + \sum_{\theta'} \Theta(\theta') \\
& \cdot \Bigg([\tilde{\lambda} + (1-\tilde{\lambda})q] \tilde{V}_i^u(A^n(a-c,\theta'\hat{n}), \Gamma(w\hat{n}), 1, t+1) \\
& + (1-\tilde{\lambda})(1-q) \Bigg[\pi \max\Big\{ V_i^n(A^n(a-c,\theta'\hat{n}), h_{o,i}, t+1), \\
& \qquad V_i^u(A^n(a-c,\theta'\hat{n}), h_{o,i}, 0, 1, t+1) \Big\} \\
& + (1-\pi) \max\Big\{ \tilde{V}_i^n(A^n(a-c,\theta'\hat{n}), \hat{n}, , t+1), \\
& \qquad \tilde{V}_i^u(A^n(a-c,\theta'\hat{n}), 0, 1, t+1) \Big\} \Bigg] \Bigg) \Bigg\}
\end{aligned} \tag{9}
$$

$$\text{subject to} \qquad c \in [0,a]\,.$$

Policy function $\tilde{c}_i^n(a,\hat{n},t)$ tells optimal consumption.

The value function for an inexperienced unemployed agent is

$$
\begin{aligned}
\tilde{V}_i^u(a,\gamma,d,t) \;=\; & \max_{c,s'} \Bigg\{ \log(c) + \beta m_t \Bigg[-B^u(s') \\
& + \tilde{S}(s') \sum_{\hat{n}'} G_i(\hat{n}') \Bigg(I\big(w\hat{n}' \geq e_{\min}\big) \max\Big\{ \tilde{V}_i^n(A^u(a-c,\gamma'), \hat{n}', t+1)\,, \\
& \qquad \tilde{V}_i^u(A^u(a-c,\gamma'), \gamma', d+1, t+1) \Big\} \\
& + I\big(w\hat{n}' < e_{\min}\big)\, \tilde{V}_i^u(A^u(a-c,\gamma'), \gamma', d+1, t+1) \Bigg) \\
& + \big[1 - \tilde{S}(s')\big] \tilde{V}_i^u(A^u(a-c,\gamma'), \gamma', d+1, t+1) \Bigg] \Bigg\}
\end{aligned} \tag{10}
$$

$$\text{subject to} \qquad c \in [0,a]\,, \quad s' \in [0,1]\,, \quad \gamma' = \begin{cases} \gamma, & \text{if } d < d_{\max}\,; \\ 0, & \text{if } d \geq d_{\max}\,. \end{cases}$$

where $I(\cdot)$ is an indicator function that is equal to one if the statement in parentheses is true and zero otherwise. Policy functions $\tilde{c}^u_i(a,\gamma,d,t)$ and $\tilde{s}_i(a,\gamma,d,t)$ give optimal levels of consumption in the current period and time spent on job search in the next period, respectively.

If the agent is still inexperienced in period T^n-1, she would optimally set $s'=0$ if unemployed, and all the continuation value functions in Bellman equations (9) and (10) are then replaced by $V^o(A^n(a-c,\theta'\hat{n}),t+1)$ and $V^o(A^u(a-c,\gamma'),t+1)$, respectively.

4.4 Firms

The value functions of an existing firm with the productivity level of z are

$$V^f(z) = \max\left\{E_n\left[\tilde{V}^f(n,z)\right], -\Omega\right\}, \tag{11}$$

$$\tilde{V}^f(n,z) = \max_k\left\{z\,k^\alpha n^{1-\alpha} - wn - (r+\delta)k\right\} + \frac{1-\lambda}{1+r}\sum_{z'} Z(z,z')V^f(z'). \tag{12}$$

Associated with the solution to an existing firm's optimization problem is a reservation productivity $\bar{z}$ that satisfies

$$E_n\left[\tilde{V}^f(n,\bar{z})\right] = \Omega. \tag{13}$$

The break-even condition for starting a new firm is

$$\mu = \frac{1}{1+r}E_n\left[\tilde{V}^f(n,z_{\text{initial}})\right]. \tag{14}$$

In a stationary equilibrium, firms that are exogenously destroyed or that choose to exit are replaced by new firms that enter with initial productivity level of z_{initial}.

5 Calibration

The annual net interest r is set equal to 4%, which is a common value in macroeconomic analyses (see e.g. Cooley (1995)).[8] The stationary population consists of 70% low-type

[8]The model period is bi-monthly but in this section on calibration, we will explicitly refer to annual rates and probabilities. With some slight abuse of notation, we continue to use variables such as the interest rate r even though these are expressed at a bi-monthly frequency in the rest of the paper.

workers and 30% high-type workers.

Following the overview of our three calibration stages in section 2.2, we first report the parameter values of government policies in section 5.1, the only primitives that differ across the two model economies of Europe and the U.S., respectively. The parameters of the first calibration stage and any observations targeted are described in section 5.2 that pertains to a simple life-cycle model, and in section 5.3 that refers to labor market transitions. In addition to the parameterization of primitives, the first stage generates layoff rates that need to be consistent with firms' optimization in the second calibration stage, which determine the parameterization of the production technology in section 5.4. Finally, section 5.5 identifies the disutility of work and the process for human capital loss in turbulent times, i.e., the third calibration stage.

5.1 Government policies

The unemployment insurance benefit $\Gamma(e)$ amounts to a replacement rate of 60% of last earnings e in both the U.S. and Europe, but the benefit is capped by a ceiling $\overline{\gamma}$ that is set at 50% of average earnings in the U.S., and at 100% of average earnings in Europe. The maximum duration of unemployment insurance $d_{\max}$ is 6 months in the U.S. but of unlimited duration in Europe.[9]

Europe has a job destruction tax Ω equivalent to three months of low-type workers' average earnings, but in the U.S. there is none. In the U.S. there is never a binding minimum wage. In Europe, the minimum wage does not bind in tranquil times, but we make it bind in turbulent times. In our indivisible-labor model, that binding European minimum wage is represented as a level of minimum earnings $e_{\min}$ equivalent to 50% of average earnings in Europe. Dolado et al. (1996) report that minimum wages in most European countries are about 50-70% of average earnings compared to about 33% in the U.S.

The labor income tax rate τ_n is set to 15% for the U.S. and 30% for Europe, while the social security payroll tax rate τ_p equals 10% on both continents. The total tax rates on labor income of 25% and 40% in the U.S. and Europe, respectively, are in line with the

[9]While unemployment insurance is typically of limited duration, Layard et al. (1991) emphasize that further benefits are often available in Europe for an indefinite period after unemployment compensation has been exhausted. Hunt (1995) describes the German policy in 1983 when unemployment compensation ('Arbeitslosengeld') replaced 68% of an unemployed worker's previous earnings and could be collected for at most 12 months. After those benefits were exhausted, means-tested unemployment assistance ('Arbeitslosenhilfe') paid a replacement rate of 58% for an indefinite period. For additional evidence on generous replacement rates and long benefit durations in Europe, see Martin (1996), who also considered housing benefits.

estimates of effective tax rates across OECD countries in Mendoza et al. (1994). The tax rate on capital τ_k is set to 15% in both the U.S. and Europe.

The social security benefit ϵ is equivalent to 40% of average earnings in the U.S. and 50% in Europe. The constant benefit implies a progressive replacement rate. According to the OECD study of Queisser and Whitehouse (2006), the average gross replacement rate in the U.S. for an individual with the average earnings is 38.6%, while it is 28.1% and 49.6% for individuals with twice and half the average earnings, respectively. The replacement rates are in general higher in Europe. The average gross replacement rate is 52.9% in France, 45.8% in Germany and 78.8% in Italy.

Recall that public consumption X is determined residually from the government budget constraint.

5.2 A simple life cycle model

To attain the target that the agents in the U.S. model own 50% of the aggregate capital stock in tranquil times, we set the subjective annual discount factor $\beta = 0.981$. Our calibration target is motivated by the fact that the 5% wealthiest U.S. households have claims on about half of U.S. wealth (see e.g. Budría Rodríguez et al. (2002)). We seek to model determinants of the remaining half of total wealth that is held by the agents in the model because our framework does not capture various mechanisms that have been identified as contributing to high degrees of wealth concentration, such as entrepreneurship and intergenerational transfers (see e.g. Cagetti and De Nardi (2008) for a survey of the literature). The disutility of work is set to $B = 0.22$, based on calibration targets to be laid out in section 5.5. Age-dependent survival probabilities m_t are taken from the life tables of Bell and Miller (2005).

Workers who are experienced can spend time ℓ to accumulate human capital according to the skill acquisition stochastic matrix $H_i^n(h, \bar{h}; \ell)$ that governs stochastic transitions from skill level h to skill level $\bar{h}$ for a worker of type i, whose initial endowment of human capital is $h_{o,i}$. The stochastic matrix is deduced from a deterministic Ben-Porath technology $h_{t+1} = h_t + A_i(h_t l_t)^\nu$ that we calibrate at an annual frequency as follows. The curvature parameter is set to $\nu = 0.8$ so that it falls in the range of estimates in the applied labor literature, e.g., see Heckman et al. (1998) whose assumption of no human capital depreciation we also adopt. We then target the difference in earnings between the two types of workers (non-college and college graduates) at ages 25 and 50: in particular, an entry-level earnings ratio of 1.6 between high- and low-type workers at age 25, and subsequent earnings growth of 60% and 110% between ages 25 and 50 for the low type and the high type, respectively. After normalizing $h_{o,L} = 1$, our calibration results in parameter values $h_{o,H} = 1.79$, $A_L = 0.049$, and $A_H = 0.066$. Appendix A describes how we map this technology into the stochastic matrix $H_i^n(h, \bar{h}; \ell)$.

The idiosyncratic labor productivity shock θ is distributed log-normally, $\log \theta \sim N(0, \sigma_\theta^2)$. The variance σ_θ^2 is set at 0.04, which lies in the range of micro estimates for the transitory components of earnings shocks, see e.g. Heathcote et al. (2010) and Guvenen (2007).

5.3 Labor market transitions

A major labor market transition is from an inexperienced to an experienced worker. Conditional on working, that happens at an annual probability of $\pi = 0.33$, i.e., it takes on average three years to become experienced. The probability distribution $G_i(\hat{n})$ of effective units of labor from which inexperienced workers draw jobs, is taken from Ljungqvist and Sargent (2008), i.e., a normal distribution with a mean of 0.7 and a variance of 0.02 that has been truncated to the unit interval $[0, 1]$ and then normalized to integrate to one. But in a twist that helps make contact with data, we splice together the earnings of inexperienced and experienced workers of each type i so that the resulting earnings profiles in figure 4.a are smooth. This is accomplished by multiplying the productivity draws from $G_i(\hat{n})$ by $\rho h_{o,i}$, where $h_{o,i}$ is the initial level of human capital for a newly experienced worker and ρ adjusts the scale of the effective units of inexperienced workers and is set at 0.9. The result is that earnings tend to increase smoothly as agents move from inexperience to experience (despite the time allocated to human capital investment and its negative effect on current earnings that will be initiated once workers become experienced).

The search technology and disutility for finding the labor market is taken from Alvarez and Veracierto (2001). Search effort $s \in [0, 1]$ yields a disutility $B^u(s) = \overline{B}^u \frac{(1-s)^\zeta - 1}{\zeta}$, and as in Alvarez and Veracierto (2001), we adopt the parameter value $\zeta = 0.98$. We set $\overline{B}^u = -B\zeta$, so that the disutility of maximum search intensity is the same as the disutility of working. Following Alvarez and Veracierto (2001), the probability of finding the job market is linear in search effort: $S(s) = \xi s$ for experienced workers and $\tilde{S}(s) = \tilde{\xi} s$ for inexperienced workers. The parameters $\xi = 0.666$ and $\tilde{\xi} = 0.764$ are calibrated so that the model matches the average unemployment duration of 3 months for both experienced and inexperienced workers.

Jobs are destroyed either by nature or by firms' decisions. We set nature's annual job destruction rate to $\lambda = 0.03$, and proceed to determine the added job destruction rate q chosen by firms as if it also were a fixed parameter in the first calibration stage. Specifically, in line with observations of Hall (1982) we seek to target around six jobs held on average over the 40-year period for age bracket 25-64, and another average of three jobs over the initial five years for age bracket 20-24. The higher turnover at the beginning of careers is attained by the extra layoffs that nature imposes on inexperienced workers, $\tilde{\lambda} - \lambda$. Our calibration yields the parameter value $\tilde{\lambda} = 0.123$ and firms' layoff rate $q_{\mathrm{US}}^{\mathrm{TR}} = 0.118$ for the U.S. economy in tranquil times, where the latter will be rationalized in the second calibration stage when parameterizing the stochastic process for firms' productivities.

Given the above targets of a 3-month average duration of unemployment for all workers, and around nine jobs held on average over a lifetime, the implied U.S. unemployment rate in tranquil times is 5.4%. Our calibration target for Europe in tranquil times is an unemployment rate that is lower by 1.5 percentage points. Since the historical record is that durations of unemployment were similar across the Atlantic in tranquil times, we 'calibrate' European firms' layoff rate to be $q_{\mathrm{EU}}^{\mathrm{TR}} = 0.049$, or more exactly, this is a second target to be rationalized in the second calibration stage when parameterizing the stochastic process for firms' productivities that will prevail on both sides of the Atlantic.

Another major labor market transition arises in turbulent times when nature's job destruction is associated with the risk of extraordinary human capital loss. The distribution of human capital h' for such a laid-off worker, as encoded in the transition probabilities $H_i^{\lambda}(\bar{h}, h')$, is the left half of a normal distribution, with the range starting at the lowest possible human capital $h_{o,i}$ and ending at the worker's human capital before the layoff $\bar{h}$. Specifically, the truncated distribution, indexed by the variance σ_{λ}^2 of the underlying normal distribution, is obtained as follows. We take the left side of a normal distribution that is confined to and centered on the unit interval. The truncated distribution is normalized to integrate to one, and is the same for every experienced worker who is laid off due to nature's job destruction. For each such laid-off worker, we merely rescale the range of the described distribution so that it starts with $h_{o,i}$ and ends at that particular worker's human capital $\bar{h}$ before the layoff. In tranquil times, the variance of the underlying normal distribution is zero, since there is no loss of human capital. In turbulent times, the variance of the underlying distribution is set to $\sigma_{\lambda}^2 = 0.306$, based on calibration targets to be laid out in section 5.5.[10]

[10] For our parameterization based on an underlying normal distribution with a mean at the worker's human capital before the layoff $\bar{h}$, and then using the truncated left half of that distribution with a range starting at $h_{o,i}$, the maximum degree of turbulence is bounded by a uniform distribution over that range. When opting

5.4 Production technology

We adopt a standard parameterization of a firm's production function: a capital share of $\alpha = 0.33$ and an annual depreciation rate of $\delta = 0.06$. Regarding a firm's job-specific productivity level z, we follow Mortensen and Pissarides (1994) who in a continuous-time model assume that the process that changes the idiosyncratic productivity is Poisson with arrival rate p_z, and when there is a change, the new value z is drawn from a fixed distribution. Analogously, our Markov transition $Z(z, z')$ at a bi-monthly frequency is as follows. Next period's productivity z' remains unchanged at value z with probability $1 - p_z$. With probability p_z, a new productivity is drawn from a normal distribution having mean 0.5 and variance σ_z^2 that has been truncated to the unit interval $[0, 1]$ and then normalized to integrate to one. In contrast to Mortensen and Pissarides (1994), who set p_z and σ_z to match job creation with data reported for U.S. manufacturing by Davis and Haltiwanger (1992), our calibration targets come from the first calibration stage where we matched the average number of jobs held by a worker over her working age.[11]

We calibrate the two parameters p_z and σ_z to fit our targeted layoff rates for the U.S. and Europe in tranquil times. The solid line in figure 2 depicts all combinations of (p_z, σ_z) for which the reservation productivity of U.S. firms is such that their annual layoff rate is $q_{\rm US}^{\rm TR} = 0.118$. The family of dashed lines describe Europe, where each dashed line is drawn for a different job destruction tax. Starting from below the seven dashed lines represent a job destruction tax equivalent to 0, 1, 2, 3, 4, 5 and 6 months of low-type workers' average earnings, respectively. Analogous to the solid line, each dashed line with its particular job destruction tax depicts all combinations of (p_z, σ_z) for which the reservation productivity of European firms is such that their annual layoff rate is $q_{\rm EU}^{\rm TR} = 0.049$. The intersection of the dashed line in the middle (that corresponds to a job destruction tax equivalent to 3 months of low-type workers' average earnings) and the solid line, at $(p_z, \sigma_z) = (0.070, 0.053)$ and marked by a bullet, rationalizes both targeted layoff rates for the U.S. and Europe,

for even higher turbulence, we can achieve that by shifting the mean of the underlying normal distribution to $h_{o,i}$, and then using the truncated right half of that distribution with a range ending at $\bar{h}$. Successively *reducing* the variance of that underlying distribution generates further increases in turbulence, and maximum turbulence is attained at a zero variance which would mean that $H_i^\lambda(\bar{h}, h_{o,i}) = 1$, so that all job destruction by nature is associated with 100% loss of accumulated human capital, i.e., any worker experiencing job destruction induced by nature ends up with her initial endowment $h_{o,i}$.

[11] While we do not seek to match job destruction data, our calibration target for the U.S. annual layoff rate (due to jobs being destroyed by nature or by firms' decisions in our model), $\lambda + (1 - \lambda) q_{\rm US}^{\rm TR} = 0.144$, is yet close to Davis and Haltiwanger's (1992) reported gross job destruction rate of 11.3% per year in the U.S. manufacturing sector over the 1972 to 1986 period.

respectively.

New jobs are created at a startup cost μ equivalent to three months of low-type workers' average earnings in the U.S. economy in tranquil times, and the productivity of a new job is $z_{\text{initial}} = 0.5$.

5.5 Disutility of work and turbulence

The parameter space in figure 3 is the disutility of work B and an index for the parameterization of extraordinary human capital loss in turbulent times. Specifically, the latter index is the average percentage loss of accumulated human capital implied by the calibration of transition probabilities $H_i^\lambda(\bar{h}, h')$.[12] We have superimposed on that parameter space two sets of isoquants – a family of downward-sloping curves pertaining to the attainment of specific European unemployment rates in turbulent times, and a set of horizontal lines pertaining to the attainment of specific percentage increases in the permanent variance of U.S. labor earnings between tranquil and turbulent times, in the way analyzed by Gottschalk and Moffitt (1994).

Each downward-sloping curve shows combinations of the disutility of work and the index for turbulence that generate a specific European unemployment rate in turbulent times. Starting from the left side those isoquants go from 7% to 20% European unemployment in turbulent times. Since our calibration target is 10%, we select the fourth isoquant from the left side. As can be seen, an unemployment target can be attained for practically any disutility of work if we make offsetting changes in the degree of turbulence. A higher disutility of work makes European workers more prone to bail into publicly funded unemployment, so we must reduce the degree of turbulence in order not to overshoot the specific unemployment rate at a given isoquant. On the right side of the figure there are vertical shaded regions that indicate problems for our underlying calibration of the model in tranquil times. In particular, when moving to the right of the first vertical line, the higher value of disutility causes higher European unemployment already in tranquil times and hence, the calibration target of a European unemployment rate that is 1.5 percentage points lower than that of the U.S. is no longer met. When crossing the second vertical line to the right, European unemployment in tranquil times is even higher than that of the U.S. And after the third

[12] Note that the percentage loss is expressed in terms of *accumulated* human capital, excluding the endowment $h_{o,i}$ that constitutes a lower bound for human capital. Hence, the highest possible loss is 100% and implies that any worker who suffers job destruction by nature would fall down to her initial endowment $h_{o,i}$. The associated transition probabilities $H_i^\lambda(\bar{h}, h')$ would equal one for $h' = h_{o,i}$, and zero otherwise.

vertical line, the European unemployment rate in tranquil times exceeds 10%. We conclude that explaining low European unemployment in tranquil times implies upper bounds on the disutility of work.[13]

As further discussed in section 6.2, we compute permanent and transitory components of earnings in the U.S. model economy. Each horizontal line in figure 3 shows combinations of the disutility of work and the index for turbulence that generate a specific percentage increase in the permanent variance between tranquil and turbulent times for high-type workers. Starting from below, those isoquants represent increases of 25%, 50%, 75% and 100%, respectively. The reason that the isoquants are perfectly horizontal is that U.S. workers are at a corner solution for career length – they retire at an official retirement age – and hence, perturbations in the disutility of work do not affect outcomes. Since Gottschalk and Moffitt (1994) report on observed increases of around 40% in the permanent variance, we pick the parameter values at the bullet point in figure 3, where the permanent variance of earnings increases by 36% for high-type workers (and by 27% for low-type workers, not shown).

While our calibration ensures that European unemployment will rise to 10% in turbulent times, and that the U.S. economy will experience some earnings dynamics reminiscent of Gottschalk and Moffitt (1994), questions remain about what the model has to say about any differences in outcomes over individuals' life cycles. We turn to these next.

6 Outcomes

Table 7 shows how our model fits aggregate labor market outcomes across the Atlantic ocean in the post-World War II era. As in the data, the unemployment rate was significantly

[13] In figure 3, we retain the parameterization from earlier calibration stages and only vary the disutility of work B and the stochastic process for human capital loss in turbulent times. So when varying B, why do we not need to recalibrate the entire model to ensure that the targets of the earlier two calibration stages are still met? The reason is that we initialized the calibration procedure with a value of the disutility of work ($B = 0.22$) that is low enough so that workers are at a corner solution for career length at the mandatory retirement age, which makes the outcomes of the first two calibration stages almost invariant to the particular choice of such a low value of B. To show that to be the case, we have recalibrated the entire model for alternative values of $B \in \{0.10, 0.15, 0.20, 0.25\}$ and found that the parameterization in the first two calibration stages are indeed virtually unchanged and as a result, they all generate isoquants for 10% European unemployment in turbulent times that lie on top of the one drawn in figure 3 for $B = 0.22$. But when choosing too high a disutility of work, e.g. $B = 0.30$, that invariance no longer holds, and it is especially the parameterization of the stochastic process for firms' productivities that change – the calibration procedure seeks to balance off the occurrence of publicly funded early retirement in Europe already in tranquil times by lowering the layoff rate of firms. Since such high values of B generate counterfactual outcomes of early retirement in tranquil times and cannot attain the two targets in the third calibration stage, we do not pursue that shaded part of the parameter space in figure 3 any further.

lower in Europe as compared to the U.S. in tranquil times (before the 1970s), but that changed dramatically after the 1970s when European unemployment more than doubled while the U.S. unemployment rate remained virtually unchanged. A mechanical explanation for Europe having a lower unemployment rate in the pre 1970s tranquil times was its lower inflow rate into unemployment while the average duration of unemployment was similar on both sides of the Atlantic. A mechanical explanation for the outbreak of high unemployment in Europe during the post 1970s turbulent times was a drastic increase in the average duration of unemployment while the inflow rate remained low and below that of the U.S., where not much changed across tranquil and turbulent times.

These aggregate statistics conceal worker heterogeneities that are critical for understanding our theory of trans-Atlantic employment experiences. To provide a background for our analysis of individual dynamics that are set off by turbulence, section 6.1 reports life-cycle outcomes implied by our model in tranquil times; in turbulent times those same dynamics characterize lives of those workers who choose to work until the mandatory retirement age. Comparing tranquil and turbulent times, section 6.2 examines how the dynamics of individuals' earnings change, and section 6.3 probes beneath the aggregate unemployment outcomes of table 7 to study individual experiences across different ages and education levels. All of our inquiries produce outcomes that are strikingly similar to the data.

6.1 U.S. outcomes in tranquil times

Figure 4 shows life-cycle profiles of earnings (panel a) and assets holdings (panel b) of U.S. low-type and high-type workers, respectively. The solid lines describe model outcomes and the dashed/dotted lines depict data. The earnings data refer to full time male workers from the U.S. Census in 2006, and the asset data are from the Survey of Consumer Finance (SCF) in 2004, depicting household holdings of financial and non-financial assets net of debt such as housing loans and other lines of credit. High-type (low-type) workers correspond to college (non-college) graduates in the data, and in the case of asset holdings, the sample does not include the top 5% of households, for reasons explained in section 5. Model outcomes resemble data in figure 4, as do the life-cycle profiles of consumption in figure 5. (See e.g. Gourinchas and Parker (2002).)

The model's upward-sloping earnings profiles are driven by workers who have by becoming experienced have acquired access to the Ben-Porath human capital technology. Figure 6 displays life-cycle profiles of average human capital (panel a) and associated investments measured as the fraction of time a worker devoted to human capital accumulation (panel b). Thanks to past achievements in this strand of research, our succeess in matching the earnings profiles of figure 4 could be anticipated. For the record, note that earnings are increasing not only because an older worker has more human capital but also because she gradually reallocates time away from human capital accumulation and toward selling the services of already accumulated human capital. That underlying investment calculus will be central in the next section when we study age-dependent changes in autocovariances of individual earnings induced by increased turbulence.

The heightened job churning of young workers during the inexperience phase introduces a concavity in the life-cycle profile of the average number of jobs held at different ages in figure 7 – a shape that roughly conforms with observations, e.g., see Hall (1982). This higher rate of inflow of inexperienced workers into unemployment gives rise to the elevated youth unemployment depicted by the dashed line in figure 8.a. That confirms a common mechanical explanation for why the youngest group of workers experience higher unemployment rates across time periods and across countries.

Figure 8 shows that U.S. unemployment outcomes in turbulent times closely resemble those in tranquil times: the unemployment rate (dashed lines) are virtually the same across tranquil times (panel a) and turbulent times (panel b). This pattern prevails despite the fact that higher human capital losses in turbulent times alter individual earnings dynamics, to which we turn next.

6.2 U.S. earnings dynamics in turbulent times

Since laid off workers are entitled to unemployment benefits for a maximum of 6 months in the U.S., the eruption of turbulence does not cause unemployment to change very much in the U.S. Instead, at our parameterization of the disutility of work, laid off American workers who experience losses of human capital choose to return to work at diminished earnings rather than to enter privately financed early retirement. We now use artificial earnings data to examine whether our model exhibits the kind of earnings dynamics observed by Gottschalk and Moffitt (1994) and Moffitt and Gottschalk (1995). It makes sense to study the two types of worker separately. We start by focusing on the high type.

Using the U.S. model economy in tranquil and turbulent times, respectively, we generate artificial versions of Gottschalk and Moffitt's PSID panels for 1970–78 and 1979–87, respectively. Applying their method for decomposing each panel's earnings into permanent and transitory components delivers figures 9.b and 10.b as our counterparts to their figures 2 and 4 (reproduced here in our figures 9.a and 10.a). Evidently, our representation of turbulence spreads the distributions of both components of the Gottschalk-Moffitt decompositions in the directions that they observed. There are differences in the ranges of the distributions. That the distribution of permanent earnings in figure 9.b spans a smaller range than do the Gottschalk-Moffitt data is not surprising. Our artificial panel contains an ex-ante homogeneous group of college graduates, while the PSID used by Gottschalk and Moffitt comprises a diverse group of American males with different educational backgrounds. It is also noteworthy that the increased earnings variability in the more turbulent period in our figure 10.b occurs at lower standard deviations than Gottschalk and Moffitt's. In this respect, the increase in economic turbulence in our parameterization for the 1980's falls short of the changes observed in U.S. data. That was also true in the simpler frameworks of Ljungqvist and Sargent (1998, 2008).

The corresponding figures for low-type workers are very similar. That might not be too surprising since our calibration of the model brings similar percentage increases in the variances of permanent earnings for both types of worker, which in turn comes from targeting the percentage increases in actual variances observed by Gottschalk and Moffitt (1994). It is sensible for us to consider low-type and high-type workers separately because merging them would result in a bimodal distribution of permanent variances. An increase in turbulence would have ambiguous effects on the variance of that blended distribution: not only would the tails gather mass but the valley between the two peaks of the bimodal distribution would change.

To illustrate forces at work, consider the following unanticipated shock to American workers in tranquil times. For a large number of randomly drawn employed workers in different age groups, let each worker experience a loss of human capital that decreases her earnings by 10 percent. Simulate their subsequent earnings until the mandatory retirement age; compare those paths to what their earnings would have been in the absence of those shocks to human capital. Outcomes of that experiment for high-type workers appear in figure 11. The nearer a worker is to the official retirement age, the lower is her propensity to invest in human capital in order to make up for the loss of human capital.

After our experiment in figure 11, one might not be surprised to learn that the artificial panel data from the U.S. model economy imply increases between tranquil and turbulent times in autocovariances of earnings of older workers, as reported in table 8. In fact, our results conform closely with the earnings dynamics documented by Moffitt and Gottschalk

(1995), who conclude that between the 1970s and 1980s, there has been "an increase in covariances ... larger for the older age groups and for the low-order covariances." The percentage changes in autocovariances in our simulated data resemble theirs, as can be inferred from figure 12 that reproduces Moffitt and Gottschalk's (1995) figure 1(d) that depicts how autocovariances by lag order in age group 45–54 evolve over the years.

In the U.S. model economy, turbulence primarily leaves its mark on earnings dynamics, not on unemployment. Things are different for people living inside the European model economy.

6.3 European unemployment experiences

A government imposed job destruction tax that suppresses the layoff rate and frictional unemployment causes the unemployment rate to be lower in Europe in tranquil times. Figure 13 shows that without that tax, unemployment in Europe would be higher than in the U.S. ,primarily due to higher unemployment benefits in Europe. At our calibration of a job destruction tax equal to three months of low-type workers' average earnings, the European unemployment rate is 1.5 percentage points lower than that of the U.S. From the historical record, the President's Committee to Appraise Employment and Unemployment Statistics (1962), appointed by President John F. Kennedy, confirmed the reliability of statistics that indicated significantly lower unemployment rates in Europe in the 1950s. That led the Deputy Commissioner of the Bureau of Labor Statistics to suspect high costs of laying off workers in Europe to be the cause.[14] Because a job destruction tax lowers unemployment by reducing the layoff rate, our model economy reproduces the observations of longer job

[14] Deputy Commissioner Robert J. Myers (1964, p. 180–181) wrote:

> "One of the differences [between the U.S. and Europe] lies in our attitude toward layoffs. The typical American employer is not indifferent to the welfare of his work force, but his relationship to his workers is often rather impersonal. The interests of his own employers, the stockholders, tend to make him extremely sensitive to profits and to costs. When business falls off, he soon begins to think of reduction in force ...
>
> In many other industrial countries, specific laws, collective agreements, or vigorous public opinion protect the workers against layoffs except under the most critical circumstances. Despite falling demand, the employer counts on retraining his permanent employees. He is obliged to find work for them to do. ...
>
> These arrangements are certainly effective in holding down unemployment."

For an analysis of why there is a strong presumption that job destruction taxes reduce unemployment in search models and in matching models in which firms are only liable to pay the tax for the workers they have chosen to hire, but not after merely encountering job seekers who are not hired, see Ljungqvist (2002).

tenures and therefore, on average, fewer jobs held by a European worker over her lifetime than by a U.S. worker, as shown in figure 7.

To appreciate why European unemployments rates explode in turbulent times, we examine an experienced worker's decision rule for job search intensity in tranquil times. In addition to her type, the state variables of an unemployed worker are her assets, human capital, last earnings (as a determinant of unemployment benefits) and age, but not the length of present unemployment spell, since there is no maximum duration of unemployment benefits in Europe. For an unemployed person who owns the average wealth level and is entitled to benefits based on average earnings in her age group, figure 14 depicts the optimal search intensity as a function of age and 'human capital loss,' i.e., how much her human capital falls below the average level in her age group as measured by accumulated human capital, excluding the endowment $h_{o,i}$ that constitutes a lower bound for human capital. The solid line is a contour for full search intensity, below which an unemployed worker chooses the highest search intensity. Between the solid and dashed lines, the optimal choice is an interior solution for search intensity; there is a corner solution above the dashed contour line for zero search intensity.[15] Figure 14 shows that a high-type worker (panel b) is more resilient to a human capital loss, choosing a higher search intensity than would a corresponding low-type worker (panel a). The explanation for this is twofold. First, Ljungqvist and Sargent (2014, sec. 3) show in a learning-by-doing framework that, off corners, the more elastic is an earnings profile to accumulated working time, the longer is a worker's career. We have verified that an analogous result holds in the present framework: in particular, if we relax the mandatory retirement age, a high-type worker with her more productive Ben-Porath human capital technology would choose a longer career than a corresponding low-type worker. Second, unemployment benefits are computed as a replacement ratio of last earnings but are subject to a maximum benefit level, which means that the effective replacement rate is higher for low-type workers because her benefits are based on lower incomes and therefore less likely to be restricted by the maximum benefit level. For these two reasons, a low-type worker is more prone to become discouraged after losing human capital and to choose a lower search intensity than would a high-type worker of the same age after the same percentage loss of human capital. Fortunately, there are no extraordinary human capital losses in tranquil times, so the European unemployment rates in figure 8.a are practically the same across

[15]The non-monotonicities of the negatively sloped contour lines in figure 14 are due to our discretization of the state space. In computations with finer grids, we obtained smoother contour lines with smaller non-monotonicities and confirmed that the computed equilibrium does not change much with finer grids.

low- and high-type workers of the same age (not shown in the figure).

It is useful to decompose European unemployment outcomes in turbulent times into two parts – first without and then with a restrictive minimum wage. If there is no minimum wage, the economic forces at work can be gleaned from figure 14, since those tranquil times decision rules in will be largely the same in turbulent times. Based on that figure, we would not expect to see any major increase in unemployment among workers of age 40 and younger because they are choosing high search intensities regardless of any human capital losses. While they potentially stand to lose considerable amounts of human capital since most of the investments are completed by age 40 in figure 6, they also have more than half of their working lives ahead of them until they reach the official retirement age of 65. In our model economy, these relatively young workers are inclined to take a new start in the labor market after any unfortunate loss of human capital. The decision rules in figure 14 show that an increasing number of workers exercise the option to bail into generous unemployment benefits as they age. This is indeed the outcome in figure 15.a where unemployment by age starts gradually to increase after age 40 as compared to tranquil times in figure 8.a. In table 9, older age groups in Europe experience increasing average durations of unemployment and a larger fraction of long-term unemployed among the unemployed of an age group. (For Europe in table 9, compare the two columns Tranquil and Turbulent*, where the asterisk indicates no minimum wage.)

The introduction of a restrictive minimum wage in Europe affects only low-type workers at the beginning of their careers, as can be seen in figure 15 by comparing turbulent times without a minimum wage (panel a) and with a minimum wage (panel b). After summing the weighted unemployment rates of low- and high-type workers in figure 15.b, we arrive at the European unemployment rate by age in turbulent times in figure 8.b (solid line). Over a life-cycle, the obstruction associated with the minimum wage is a transient phenomenon: prime-age European workers suffer no higher unemployment rates than do prime-age American workers. The end-of-career elevated unemployment is a very different issue. As noted by OECD (2003, chap. 4), some of these workers might be found in government provided disability insurance and early retirement programs, but they are actually unemployed rather than unable to work. Having said that, our European model economy serves the majority of workers well. Those (1) who are not unduly impacted by the minimum wage, and (2) who do not suffer untimely human capital losses and them become induced by generous benefits to withdraw into early retirement will lead lives like they would have had if times had remained tranquil. In portraying the distribution of years out of work over an individual's working age, figure 16 provides a perspective on how different European workers were affected by living in turbulent instead of tranquil times. Despite a thicker tail to the right with more than five years out of work, the majority of Europeans in turbulent times are idle less than twice the mean of 1.9 years in tranquil times. The U.S. distributions (not shown) are practically unchanged over time. They resemble the European distribution in tranquil times but somewhat shifted to the right with a mean of 2.6 years out of work over an individual's working age, due to the higher rates of job churning in the U.S. (see figure 7).

7 Concluding remarks

Our heterogeneous-agent life-cycle model extends a line of research about how observed increases in labor earnings variability contributed to an outbreak of persistently higher unemployment in Europe after the 1970s. After incorporating key components of earlier studies into the present framework and adopting standard parameterizations from related macroeconomic analyses, we have confirmed predictions of those earlier papers and gone on to derive additional implications that are also born out by data. A brief overview of this line of inquiry helps us to appreciate the forces at work in our present framework and to describe challenges that remain for macro-labor studies in general, and for analyses of trans-Atlantic employment experiences in particular.

In Ljungqvist and Sargent's (1998, 2008) extensions of a McCall (1970) style search model, risk-neutral workers maximize expected present values of lifetime labor earnings and unemployment benefits while accumulating human capital through learning by doing. Since benefits are a fraction of last earnings, their choices of high reservation wages and low search intensities make laid-off agents who suffer large losses of human capital prone to become long-term unemployed. Ljungqvist and Sargent (2008) extended the theory by modifying two assumptions. In order to study life-cycle dynamics and how layoff costs can suppress frictional unemployment and thereby explain why Europe had lower unemployment than the U.S. in tranquil times, they replaced (i) perpetual youth and and a constant probability of retiring, and (ii) a drawn wage (per unit of human capital) staying constant over the duration of an accepted job with (i') stochastic aging that send workers through age classes until retirement, and (ii') occasional new wage draws at a continuing job. Those two new features remain central to our present model.

Ljungqvist and Sargent (2006) compared their turbulence theory to Prescott's (2005) attribution of low European employment to high tax rates. That inquiry proceeded in two parts, and its implications are central to the present paper. First, when including European-style benefits within Prescott's employment lotteries model, Ljungqvist and Sargent (2006) reverse the puzzle that Prescott had set out to study, namely, why Europeans work so little, became the opposite one: putting generous benefits into that employment lotteries model with its high labor supply elasticity causes employment to plummet far more than what Prescott had observed and hence, the puzzle now becomes why Europeans work so much. Second, as summarized in footnote 3, it turns out that employment lotteries are not necessary, because a similar high labor supply elasticity emerges in a time averaging model when career lengths are at interior solutions. Thus, our present analysis balances these forces by moving workers on and off corner solutions associated with an official retirement age.

Our analysis incorporates the turbulence mechanism within an environment that also includes important features and outcomes that researchers from various traditions will recognize: changes in unemployment rates and incidences of long-term unemployment across age and education square well with post-World War II outcomes; life-cycle profiles of consumption and asset holdings are in line with the evidence; the Ben-Porath human capital technology is parameterized in a standard way and hence, earnings profiles conform with earlier estimates; and if earnings data is simulated from our model and then sent to Gottschalk and Moffitt (1994) with the instruction that it pertains to two distinct groups of high school only and college graduates, respectively, it might pass as an addition to their empirical data. Moreover, by incorporating a Ben-Porath human capital technology that way we do implies age-dependent increases in autocovariances of income shocks, finding that makes contact with the empirical study of Moffitt and Gottschalk (1995).

Our work in this paper illustrates what we see as constructive developments in macro-labor today. Discarding an aggregation theory based on empirically dubious employment lotteries in favor of a time-averaging life-cycle framework brings macroeconomic work closer to a longstanding tradition in labor economics based on the life-cycle model. That is progress because it facilitates constructive exchanges between macro and labor researchers who have come to opposite conclusions about magnitudes of labor supply elasticities. The life-cycle framework promises to focus macroeconomic researchers' attention on the microeconomic observations about lifetime labor supply, observations ignored when the lotteries model prevailed among macroeconomists. That can spur research that might lead to the labor supply elasticity accord foretold by Ljungqvist and Sargent (2011). As emphasized by Rogerson and Shimer (2011, p. 690),

> "There is potentially a lot of useful information in the disaggregated data that

> may help to distinguish competing theories. ... we note two findings here: unemployment differences are particularly pronounced among younger workers, while employment differences are particularly pronounced both for younger and older (but not prime-aged) workers. More generally, incorporating differences in age, gender and skill level may be useful for distinguishing theories of labor market outcomes. ... Kitao et al. [present paper] is a recent example that moves in this direction."

Our model sends inexperienced workers through a phase of job search during which they suffer exogenous job losses at higher rates than they will later in life. They draw productivities from a McCall (1970) style offer distribution. Working allows a youth stochastically to "become experienced", which means moving to a second phase in which the worker acquires access to a Ben-Porath human capital technology. Hard wired into our model, the phase of inexperience generates outcomes observed early in careers. It helps us meet two challenges to explaining the increase in European youth unemployment. First, since young workers have little human capital to lose, our turbulence dynamics cannot explain higher youth unemployment. Second, because the returns to becoming experienced are large in our framework, it requires a substantial friction somehow to hinder young workers from starting their careers. We take that friction to be a binding European minimum wage after the 1970s. That minimum wages are higher in Europe than the U.S. is beyond dispute, but there is disagreement about the implications of that fact for employment.

To illustrate opposing opinions about the employment effects of minimum wages, we return to France in figure 1 as our representative of Europe. Using data for 1990-1998 from the French Labor Force Survey, Abowd et al. (2000) find strong negative effects on future employment probabilities of workers whose current real wage falls between the current real minimum wage and a future increased real minimum wage. Using the same data source for the year 1981–1989, Dolado et al. (1996) assemble similar evidence for negative employment effects of the minimum wage but suggest that the business cycle could be a confounding factor. They proceed to discuss observations and explanations that point in different directions before concluding that "French evidence suggests that the substantial rise in the SMIC [minimum wage] to the mid-1980s had no adverse effect on employment" (Dolado et al. 1996, p. 343). Both of these papers mention the growing importance of publicly funded programs that either combine education with work or provide low-wage subsidized employment. Abowd et al. (2000) declare that their study excludes workers whose participation in such programs have earned them legal exemption from the minimum wage. After noting the dramatic growth in coverage of those programs from 8000 participants in 1976 to about 900,000 in 1993, along with an OECD report stating that the average wage for French teenagers in 1987 actually fell below the SMIC, Dolado et al. (1996, p. 338) go on to say that "this should be taken not as evidence that the SMIC is set at a very high rate, but as an indication that the SMIC is not the effective minimum wage for these workers." That conclusion puzzles us because if we were to include those complications in our model, it would certainly be evidence of too high a minimum wage. The frictions involved when firms and workers seek to win exemptions or employment subsidies might help explain why the average duration of unemployment rose from 3.3 months to 7.5 months for the youngest age group in our European model economy after the minimum wage became binding.

Our model of trans-Atlantic employment experiences contains two independent building blocks – effective minimum wages in Europe and increased turbulence on both sides of the ocean. Our model imputes detrimental employment effects to those high European minimum wages while confirming robustness of earlier turbulence theory of European unemployment and then confirming that turbulence in the present extended framework brings additional forces that improve fits to observations on earnings dynamics. The empirical evidence that we take as the tell-tale signs for an increase in our notion of economic turbulence since the 1970s continues to accumulate – from Katz and Autor's (1999) demonstration that Gottschalk and Moffitt's (1994) findings are robust across a variety of studies and data sets to Kambourov and Manovskii's (2008) documenting that there occurred a substantial increase in occupational and industry mobility in the U.S. over the period 1968–1997.

A Skill acquisition technology

For a given state of human capital h_t at the beginning of a period year and a choice l_t of investment in human capital, the deterministic Ben-Porath technology $h_{t+1} = h_t + A_i(h_t l_t)^\nu$ would tell us h_{t+1} should be at the end of the year. We have to adapt that outcome because we discretize the state space by insisting that h lie on one of the 20 grids of human capital. We design stochastic transition matrices that guarantee that the mathematical expectation of h_{t+1} is the outcome predicted by the deterministic Ben-Porath technology $h_{t+1} = h_t + A_i(h_t l_t)^\nu$. For example, suppose that h_t is 1.0 (grid point number 1) and that $h_{t+1} = 1.2$ is implied by plugging a particular choice of l_t into the deterministic Ben-Porath technology; and suppose that the two nearest grid points are grid point number $1 = 1.0$ and grid point $2 = 2.0$. Then conditional on being at grid 1 today we would set the transition probability of going to grid point 2 tomorrow to $p(1,2) = 0.2$, and similarly we would set $p(1,1) = 0.8$.

To compute the transition matrix under our bi-monthly frequency, we guess and iterate. First of all, we make sure that agents do not want to travel more than one grid point over a period of one year (this is just to simplify computations). For each state, choice pair h_t, l_t, we first guess that the probability of staying at the current grid in the next period (in two months) is $\bar{p}$. We can then compute recursively the expected human capital in each period up to the beginning of the next year, that is, in 6 model periods, or 12 months. We check if it coincides with what it should be according to the deterministic Ben-Porath technology, and adjust $\bar{p}$ until we achieve the right value. We search in this way for all h_t, l_t combinations to compute the entire transition matrix $H_i^n(h_t, h_{t+1}; l_t)$.

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Table 1: States and decisions

Variable	Meaning
i	worker type (low or high)
t	age
a	assets
c	consumption
s	search intensity
γ	UI benefits
d	elapsed duration of unemployment
h	human capital
l	investment in human capital
n	efficiency units of labor ($\theta\hat{n}$)
$\hat{n}$	effective labor (before earnings shock)
θ	worker earnings shock
z	firm productivity shock
k	physical capital

Table 2: Value functions

Value function	phase of life	decisions
$\tilde{V}_i^u(a,\gamma,d,t)$	inexperienced, unemployed	c, a', s
$\tilde{V}_i^n(a,\hat{n},t)$	inexperienced, employed	c, a'
$V_i^u(a,h,\gamma,d,t)$	experienced, unemployed	c, a', s
$V_i^n(a,h,t)$	experienced, employed	c, a', l
$V^o(a,t)$	old, retired	c, a'
$V^f(z)$	firm	$\{$operate, exit$\}$, k

Table 3: Government policies

	Description	U.S.	Europe
$d_{\max}$	UI maximum duration	6 months	unlimited
$\Gamma(e)$	UI with previous earnings e	60% replacement	60% replacement
$\overline{\gamma}$	maximum UI	50% avg. earn	100% avg. earn
Ω	job destruction tax	none	3mos of low-type earn
$e_{\min}$	minimum wage	none	50% avg. earn but only in turbulent times
τ_n	labor tax rate	15%	30%
τ_p	social security tax rate	10%	10%
τ_k	capital tax rate	15%	15%
ϵ	social security benefits	40% avg. replacement	50% avg. replacement
X	public consumption	residual	residual

Table 4: Parameters of a simple life-cycle model (annual frequency)

Parameter	Description	Value
Preferences, demographics and interest rate		
β	subjective discount factor	0.98141
B	disutility of work	0.22
m_t	survival prob. at age t	Bell and Miller (2005)
r	net real interest rate	0.04
Human capital technology		
ν	Ben-Porath curvature parameter	0.8
A_i	Ben-Porath multiplicative parameter	$A_L = 0.04924$, $A_H = 0.06616$
$h_{o,i}$	initial human capital	$h_{o,L} = 1.0$, $h_{o,H} = 1.78507$
$H_i^n(h, \bar{h}; l)$	Ben-Porath discretization: transition prob. $h \Rightarrow \bar{h}$, given investment l	see Appendix A
$\Theta(\theta)$	prob. dist. of worker earnings shock	$\log \theta \sim N(0, 0.04)$

Table 5: Parameters for labor market transitions

Parameter	Description	Value
Search disutility and technology		
ζ	search disutility curvature parameter	0.98
$\overline{B}^u$	search disutility multiplicative parameter	$-0.22 \cdot 0.98 \ = \ -B\,\zeta$
ξ	search technology parameter (experienced)	0.66584
$\tilde{\xi}$	search technology parameter (inexperienced)	0.76410
Probabilities of job termination		
λ	prob. of exogenous job destruction	0.03 (annual)
$(\tilde{\lambda} - \lambda)$	prob. of additional exogenous job separation for inexperienced workers	0.09253 ($\tilde{\lambda} = 0.12253$)
q	prob. of firms destroying jobs	endogenous
Career phase of inexperience		
π	prob. of becoming experienced	0.33 (annual)
$G_i(\hat{n})$	prob. dist. of effective labor $\hat{n}$, from which an inexperienced worker of type i draws	$\hat{n} \sim N(0.7, 0.02)$ and range truncated to $[0, 1]$
Human capital loss upon exogenous job destruction		
$H_i^{\lambda}(\bar{h}, h')$	prob. of h' for worker with beginning-of-period $\bar{h}$, deduced from left half of truncated normal dist., where underlying distribution is $N(\bar{h}, \sigma_{\lambda}^2))$	$\sigma_{\lambda}^2 = 0$ (tranquil) $\sigma_{\lambda}^2 = 0.3059$ (turb.)

Table 6: Parameters of production technology

Parameter	Description	Value
α	capital share in prod. function	0.33
δ	capital depreciation rate	0.06 (annual)
μ	startup cost for a new job	3mos of low-type earn
z_{initial}	productivity of a new job	0.5
$Z(z, z')$	transition prob. for productivity: random draw with prob. p_z at which $z' \sim N(0.5, \sigma_z^2)$ and range truncated to $[0, 1]$	$p_z = .069550$ $\sigma_z = 0.05344$

Table 7: Unemployment outcomes

	U.S.		Europe	
	Tranquil	Turbulent	Tranquil	Turbulent
Unempl. rate (percent)	5.39	5.45	3.90	9.99
Unempl. duration (months)†	3.00	3.01	3.21	12.93
Inflow rate (percent)⋆	3.41	3.45	2.16	2.22
Outflow rate (percent)⋆	66.6	66.5	62.8	23.2

† Cross-sectional average duration of all spells in progress

⋆ At bi-monthly model frequency

Table 8: Percentage increase between tranquil and turbulent times in autocovariances of annual earnings at different lag orders for high-type workers in the U.S.

Lag order	Age group 25–34	35–44	45–54
1–4	5.4	25.3	54.1
5–9	2.6	15.0	39.4
10–15	3.0	5.3	23.4

Table 9: Unemployment duration and long-term unemployment by age in Europe.

	Unempl. duration (months)			Long-term unempl. (percent of unempl.)		
Age	Tranquil	Turbulent	Turbulent⋆	Tranquil	Turbulent	Turbulent⋆
20-29	3.29	7.51	3.31	0.51	16.42	0.50
30-39	3.17	6.20	3.42	0.37	11.61	0.69
40-49	3.01	7.58	8.11	0.17	16.13	18.36
50-59	2.99	17.34	19.13	0.14	47.94	51.53
60-	3.35	26.36	29.16	0.29	63.77	66.61
All	3.21	12.93	14.70	0.40	31.40	33.55

⋆ Without the minimum wage

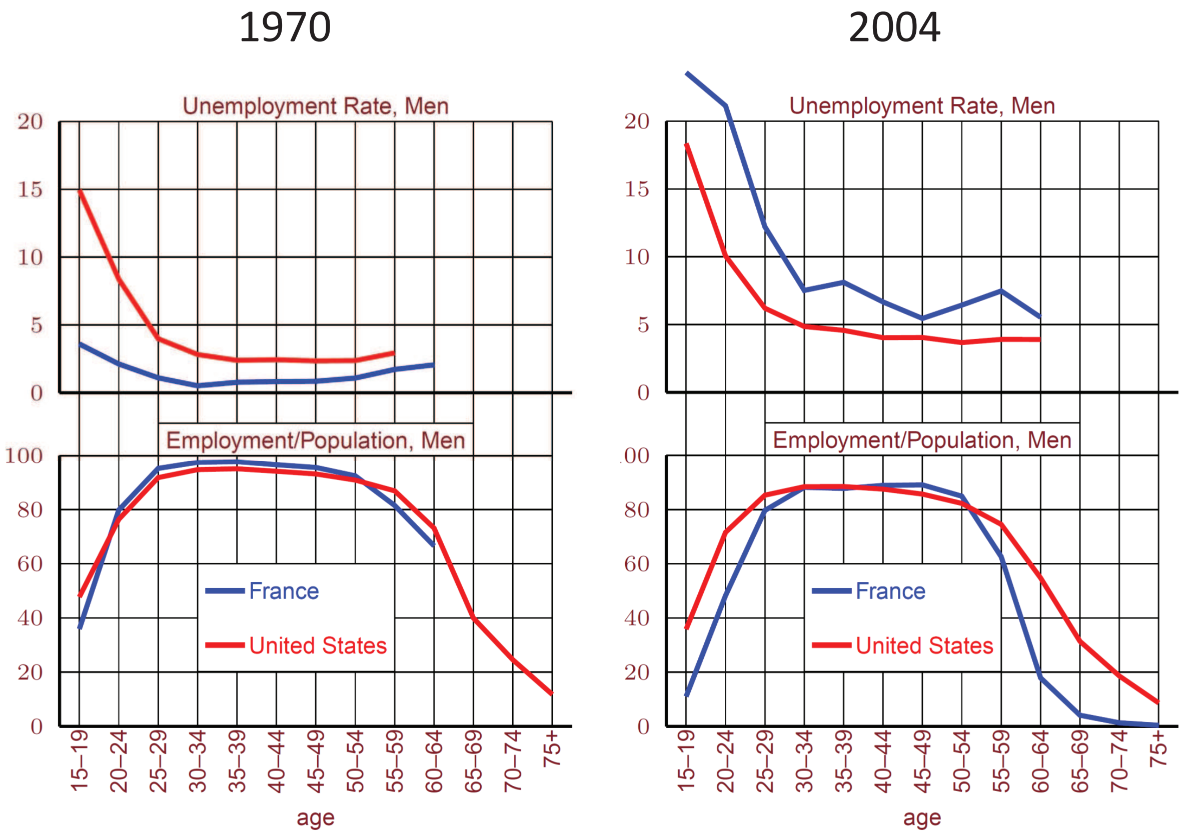


Figure 1: Male unemployment and employment-population rates (in percent) by age in France and the U.S., respectively, in 1970 (left panel) and 2004 (right panel). Source: OECD (by courtesy of Robert Shimer).

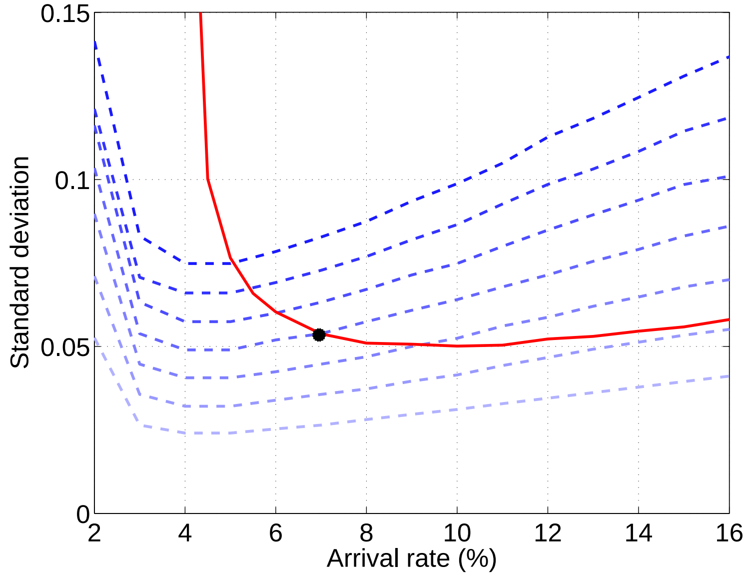


Figure 2: Isoquants for firms' layoff rates as functions of the productivity process, defined by the bi-monthly arrival rate of shocks (p_z) and the standard deviation (σ_z). The solid line is the isoquant for a U.S. annual layoff rate of 11.8%. The family of dashed lines are isoquants for a European annual layoff rate of 4.9%, given different job destruction taxes. Starting from below, the dashed lines represent taxes from 0 to 6 months of low-type workers' average earnings, respectively.

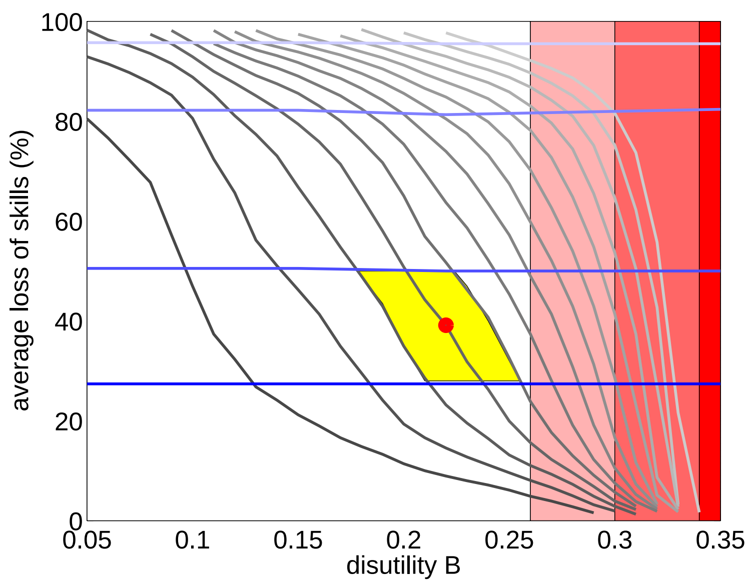
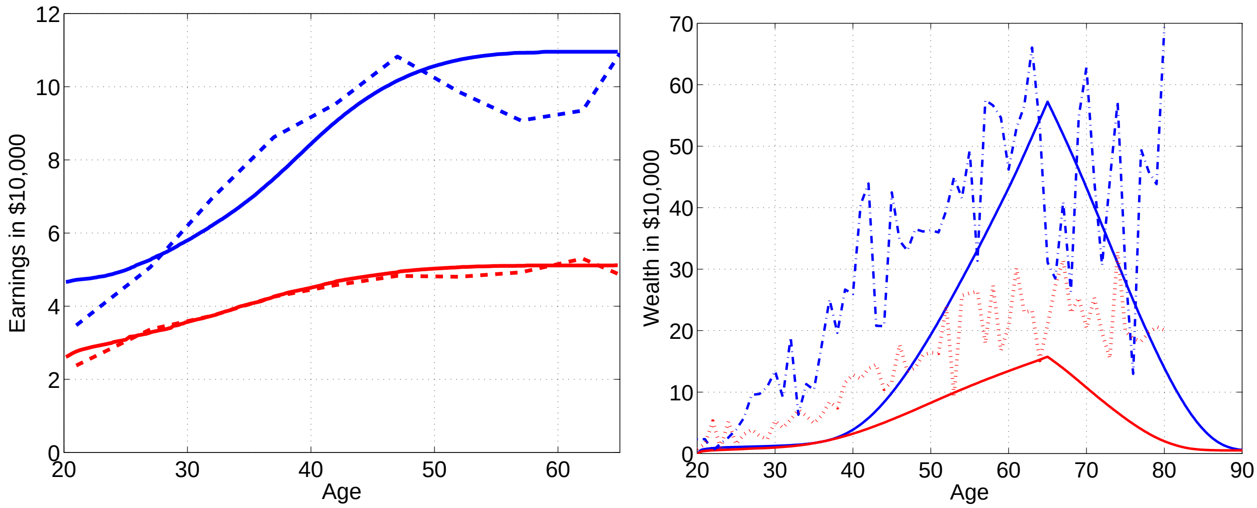


Figure 3: See section 5.5.



(a) Earnings (b) Assets

Figure 4: Earnings (panel a) and assets (panel b) as a function of age in the U.S. The solid lines describe outcomes in the model and the dashed lines depict U.S. data, where the upper (lower) pair of a solid and a dashed line refer to high-type (low-type) workers who correspond to college (non-college) graduates in data.

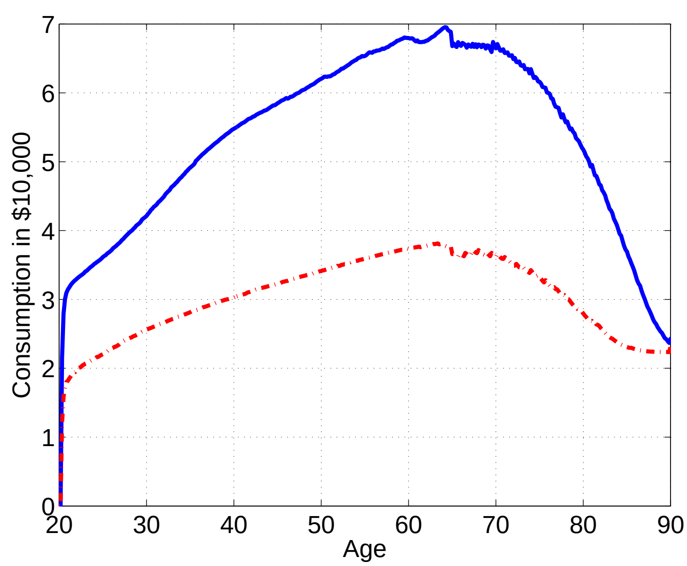
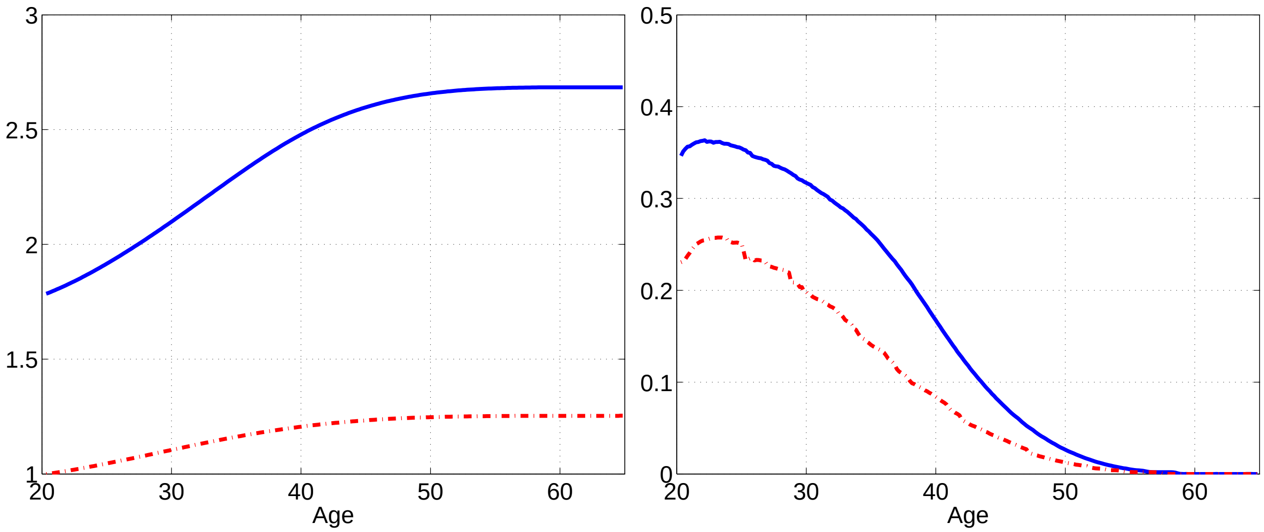


Figure 5: Consumption as a function of age in the U.S. The solid line is high-type workers and the dashed line is low-type workers.



(a) Human capital (b) Investments

Figure 6: Human capital (panel a) and investments in human capital (panel b) as a function of age in the U.S. in tranquil times. The solid line is high-type workers and the dashed line is low-type workers.

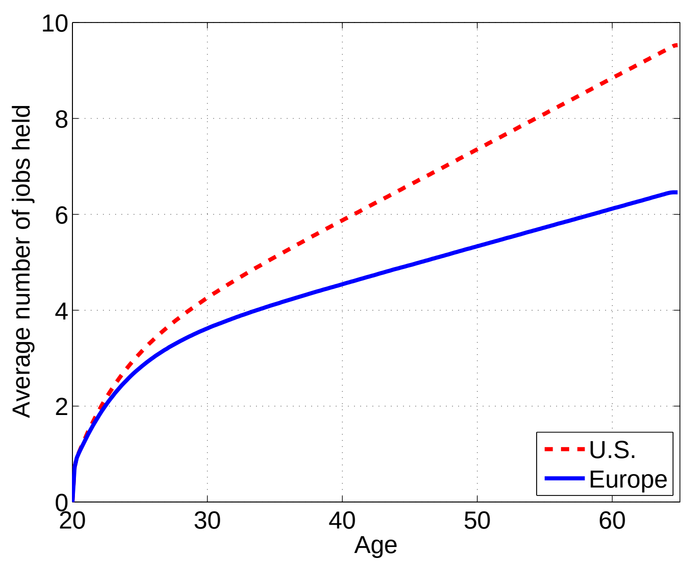
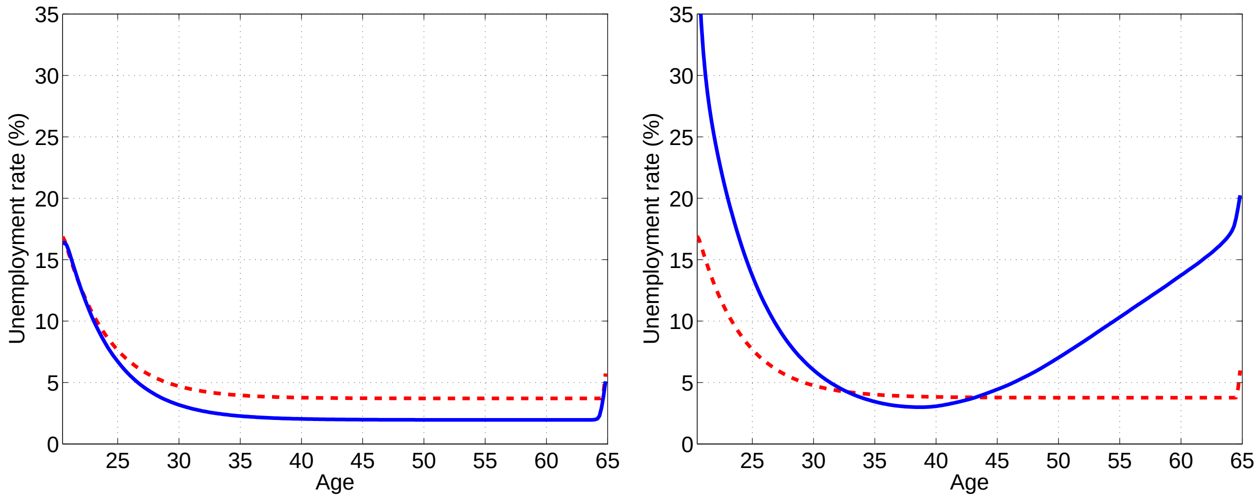
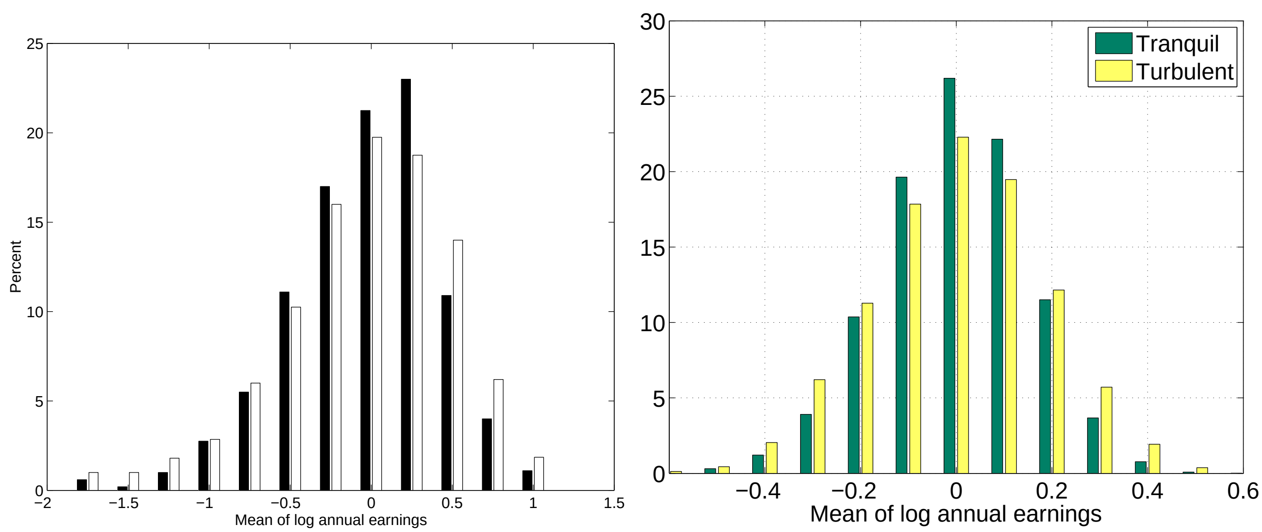


Figure 7: Workers' average number of jobs held at different ages in tranquil times. The solid line is Europe and the dashed line is the U.S



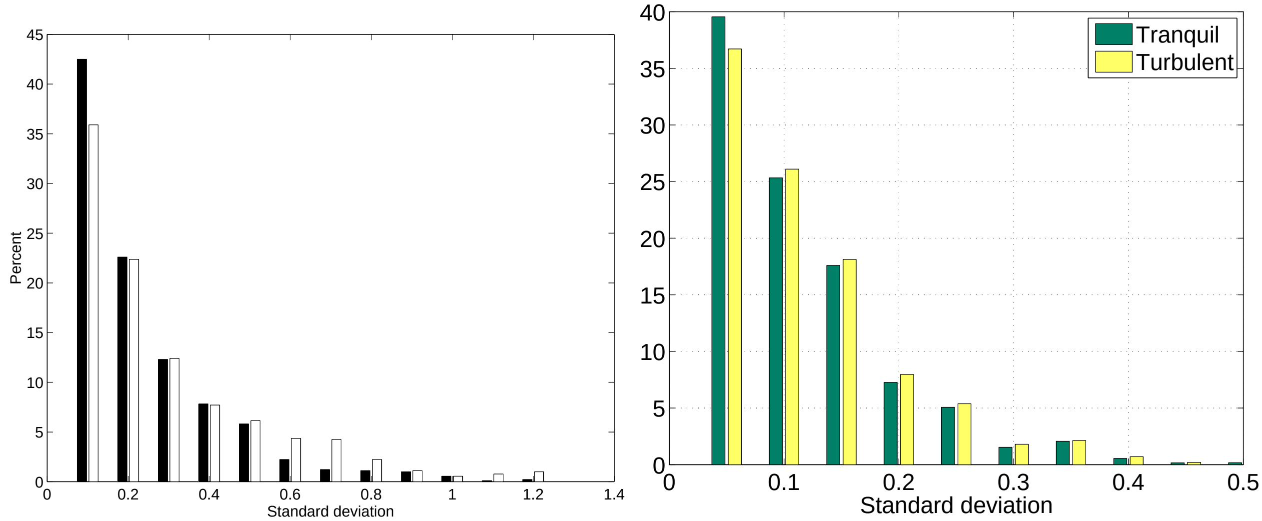
(a) Tranquil times (b) Turbulent times

Figure 8: Unemployment rates as a function of age. The solid line is Europe and the dashed line is the U.S in tranquil times (panel a) and in turbulent times (panel b).



(a) Data (b) Model

Figure 9: Distribution of permanent earnings in the U.S. The dark bars and the light bars correspond to tranquil and turbulent times, respectively, as taken from Gottschalk and Moffitt (1994, fig. 2) (panel a) and our model (panel b).



(a) Data (b) Model

Figure 10: Distribution of standard deviations of individuals' transitory earnings in the U.S. The dark bars and the light bars correspond to tranquil and turbulent times, respectively, as taken from Gottschalk and Moffitt (1994, fig. 4) (panel a) and our model (panel b).

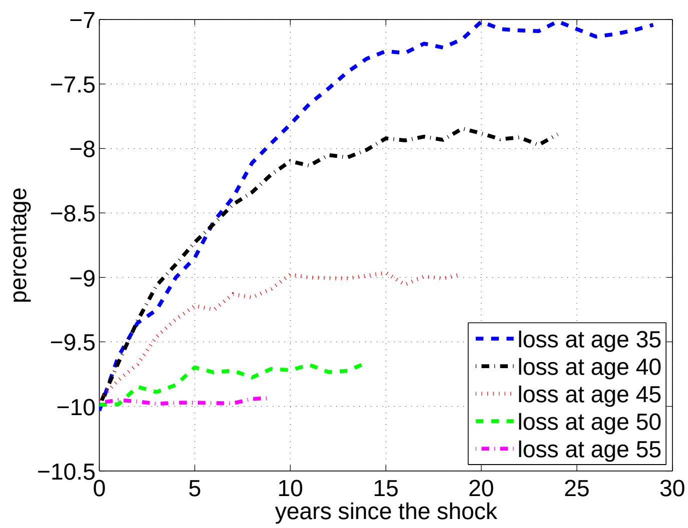


Figure 11: Earnings loss relative to the age-earnings profile for high-type workers in the U.S. in tranquil times, after a hypothetical one-time loss of human capital that causes an initial decline in income by 10%. The curves refer to representative samples of the population at age 35, 40, 45, 50 and 55, respectively, for whom the lengths of remaining income data span 29, 24, 19, 14 and 9 years, respectively.

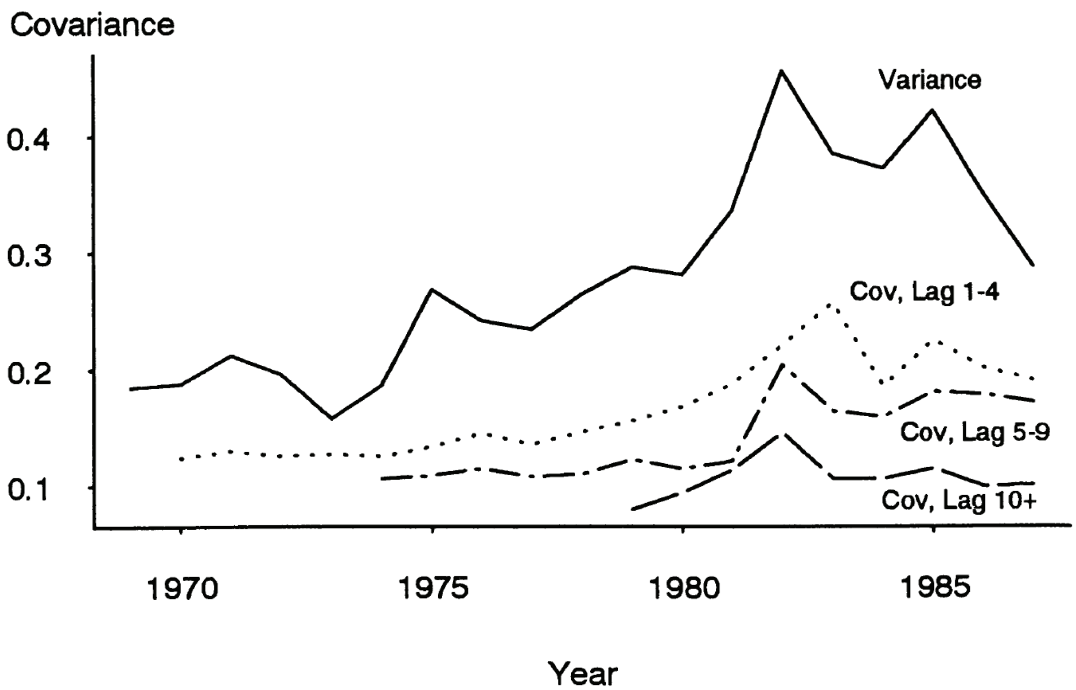


Figure 12: Empirical log earnings variances and covariances by year and by lag order in age group 45–54 in the U.S. Source: reproduction of Moffitt and Gottschalk (1995, figure 1(d)).

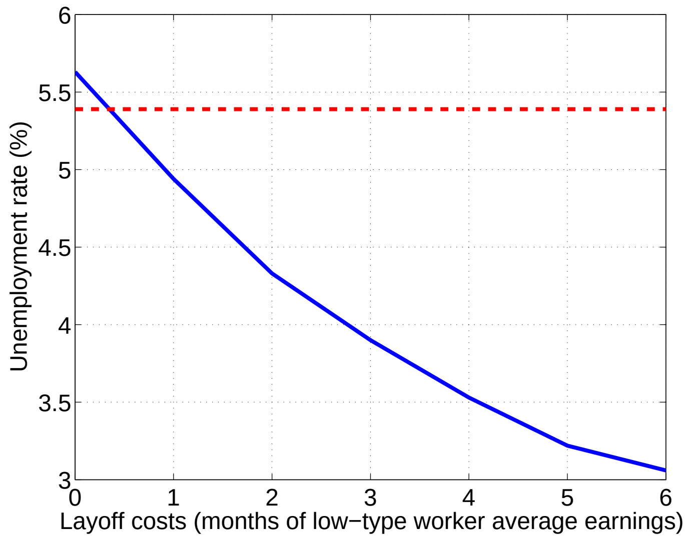
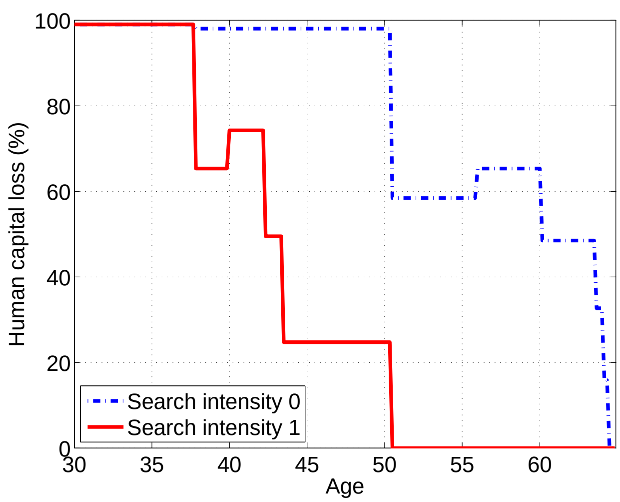
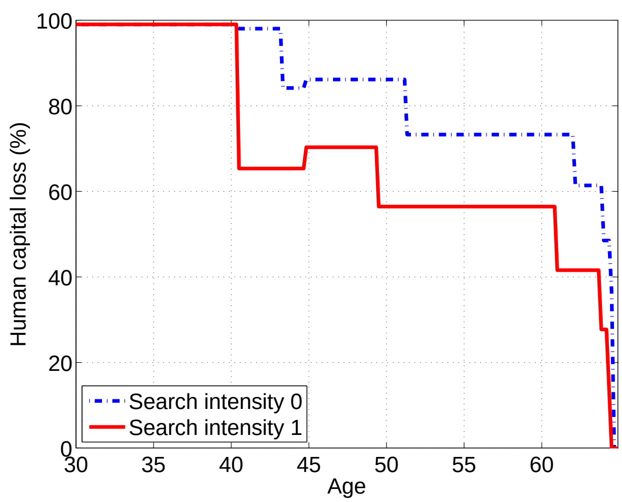


Figure 13: Unemployment rate as a function of layoff costs in Europe in tranquil times. Layoff costs are measured in terms of months of low-type workers' average earnings.

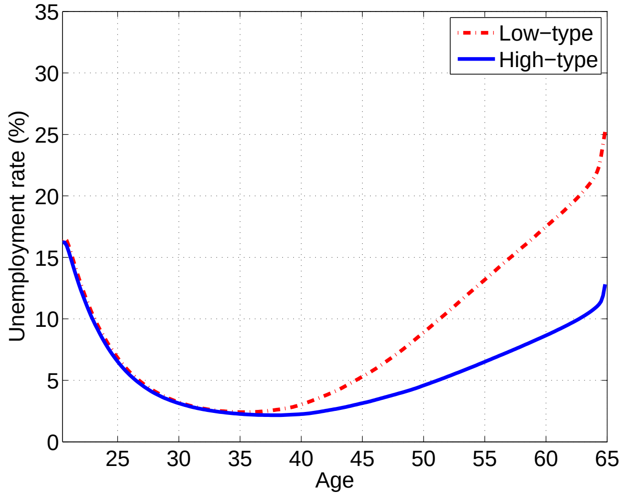


(a) Low type

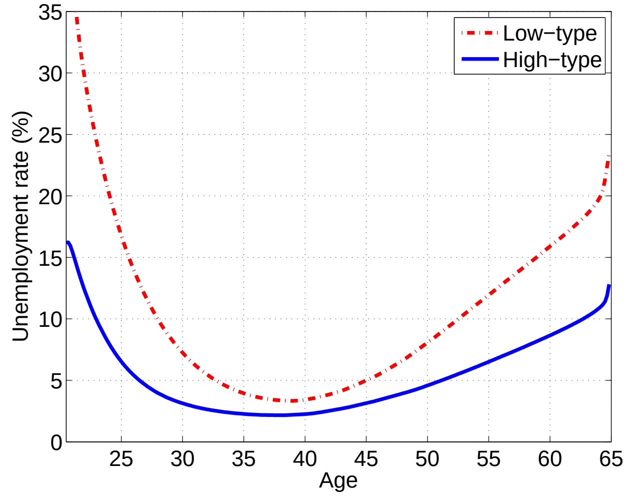


(b) High type

Figure 14: Optimal search intensity of the average low-type worker (panel a) and high-type worker (panel b) in Europe in tranquil times, as a function of age and 'human capital loss'. The agent is assumed to hold the average wealth level and to be entitled to benefits based on average earnings in her age group. The search intensity is plotted for different levels of human capital below the average level in her age group, where the difference between these numbers is interpreted as her 'human capital loss'. The solid (dashed) line is the contour curve for full (zero) search intensity.



(a) Without minimum wage



(b) With minimum wage

Figure 15: Unemployment rates as a function of age in Europe in turbulent times without a minimum wage (panel a) and with a minimum wage (panel b). The solid line is high-type workers and the dashed line is low-type workers.

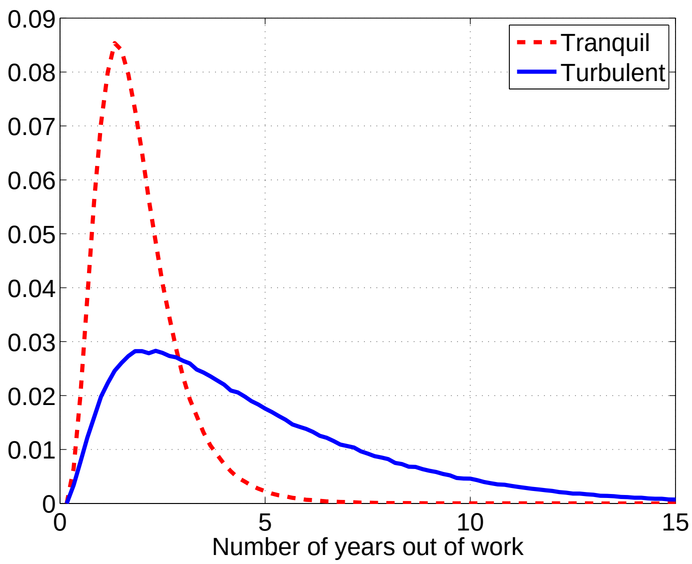


Figure 16: Distribution of number of years out of work over an individual's working age in Europe. The dashed line is tranquil times and the solid line is turbulent times.