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European Unemployment: From a Worker's Perspective

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1. INTRODUCTION

This chapter summarizes and extends our supply side explanation of two striking patterns in unemployment for Europe and the rest of the OECD (see Figure 1 and Table 1).[1] First, average unemployment performances for Europe were similar to the rest of the OECD during the 1960s and 1970s, but since the 1980s unemployment in Europe has persistently exceeded the average unemployment rate in the OECD by around two percentage points. Several European countries in fact saw their unemployment rates double between those periods. Second, since the 1980s, the average *duration* of unemployment spells in Europe has greatly exceeded that in the rest of the OECD. We attribute these patterns to the incentive effects on labor supply of the far more generous unemployment compensation arrangements in Europe.[2]

Our explanation of the broad patterns is in terms of how shocks and institutions shape workers' incentives to supply labor: random *shocks* that end workers' jobs and diminish their human capital when jobs end and public *institutions* that subsidize unemployed workers. We confront the observation that unemployment compensation arrangements have been more generous in Europe *throughout* the post–World War II period, during the first part of which European unemployment

1. This chapter builds on Ljungqvist and Sargent (1998), which contains a rigorous description of our model.

2. The notion of unemployment compensation should be interpreted broadly in our framework. The welfare states have various programs assisting individuals out of work. For example, totally disabled persons in the Netherlands in the 1980s were entitled to 70% (80% prior to 1984) of last earned gross wage until the age of 65—after which they moved into the state pension system. At the end of 1990, disability benefits were paid to 14% of the Dutch labor force and 80% of them were reported to be totally disabled (see OECD, 1992b).

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Figure 1. Unemployment rate in OECD as a percent of the labor force. The solid line is unemployment in the European OECD countries and the dashed line is unemployment in the total OECD. (Source: Data for 1961–1977 are from OECD [1984a], and data for 1978–1994 are from OECD [1995].)

was *not* higher than for the rest of the OECD. We attribute the rise in unemployment in Europe after 1980 to a change in the environment that raised the value of adaptability by workers who are forced to change jobs by changing conditions. During the more tranquil times prior to 1980, there was a lesser role for adaptability, so that a generous unemployment compensation system could coexist with low unemployment rates. However, when the required adaptability increased after 1980, that generous unemployment compensation system propelled European economies into persistently high unemployment.[3]

3. In contrast to our labor supply explanation, early theories of European unemployment focused on a shortfall in the demand for labor owing to insufficient aggregate demand (Blanchard et al., 1986), trade union behavior driven by insider-outsider conflicts (Blanchard and Summers, 1986; Lindbeck and Snower, 1988), hiring and firing costs (Bentolila and Bertola, 1990), and capital shortages (Malinvaud, 1994). Our analysis will instead bear out the assertion by Layard et al. (1991, p. 62) that the "unconditional payment of benefits for an indefinite period is clearly a major cause of high European unemployment." However, our model differs sharply from their framework, which emphasizes hysteresis and nominal inertia in wage and price setting. Independently of our work, Bertola and Ichino (1995) pursued the same idea that increased economic turbulence might explain the outbreak of high European unemployment but once again their mechanism hinged on rigid wages

Long-term unemployment is the heart of the European unemployment problem. According to Table 1, workers unemployed for 1 year or more today constitute about half of all unemployment in the European OECD countries. This stands in sharp contrast to earlier decades that saw much less long-term unemployment as well as a shorter duration of unemployment. Sinfield's (1968) study established that, except for Belgium, long-term unemployment was not much of a problem in Europe in the 1960s. Defining "long-term" as 6 months or more, Sinfield concluded that long-term unemployment typically affected 0.5 percent of a country's labor force. In countries such as former West Germany and the Scandinavian countries, it was less than 0.2 percent.

2. A SEARCH MODEL OF UNEMPLOYMENT

To study the level and duration of unemployment, we use a "lake and streams" model (see Figure 6 in Section 4 for an example with several lakes). We posit enough lakes and streams, that is, *states*, to capture what we see as important aspects of the situation confronting European workers. We begin with John McCall's simple two-lake, two-streams (two-state) model and then describe the way we extend it.

The McCall Worker. A simple version of McCall's (1970) search model sees workers moving between the two states of being employed and being unemployed. Each state defines a "lake." The flows between them define "streams." At the beginning of each period that he is unemployed, a worker receives one offer to work at a job with a fixed wage drawn from a time-invariant cumulative distribution function $F(w)$. He can take or leave the offer, with no opportunity to recall rejected offers. Successive draws from F are independent. At the beginning of each period that he is employed, the worker is exposed to a probability $\lambda \in (0, 1)$ of being cast into unemployment during that period. If he lives forever and sets reservation wage $\overline{w}$ for accepting wage offers, he spends a fraction

$$U = \frac{1/[1 - F(\overline{w})]}{1/\lambda + 1/[1 - F(\overline{w})]} \tag{1}$$

of his life unemployed. In this two-state model, workers have average spells of employment of $1/\lambda$ and average spells of unemployment of $1/[1 - F(\overline{w})]$. If the economy is populated by a fixed large number of ex ante identical such workers who make independent draws from the wage offer distribution F and the Bernoulli job-extinguishing distribution with parameter λ, then U is also the aggregate unemployment rate in every period. Thus, equation (1) justifies an analysis of the unemployment rate, such as the one of Layard et al. (1991) described in

and high firing costs that reduced labor demand. Since then, there have been several studies focusing on the interaction between a change in the economic environment and welfare-state institutions, and some of those have emphasized negative labor supply effects of generous benefits, e.g., Mortensen and Pissarides's (1999) model of skill-biased technology shocks. However, these models commonly fail to produce long-term unemployment or falling hazard rates of individual unemployed workers, features that we think are crucial for understanding high European unemployment.

Table 1. Unemployment and Long-Term Unemployment in OECD

	Unemployment (%)			Long-term unemployment of 6 months and over (% of total unemployment)			Long-term unemployment of 1 year and over (% of total unemployment)			
	1974–1979[a]	1980–1989[a]	1995[b]	1979[c]	1989[d]	1995[e]	1970[f]	1979[c]	1989[d]	1995[e]
Belgium	6.3	10.8	13.0	74.9	87.5	77.7	. . .	58.0	76.3	62.4
France	4.5	9.0	11.6	55.1	63.7	68.9	22.0	30.3	43.9	45.6
Germany[g]	3.2	5.9	9.4	39.9	66.7	65.4	8.8	19.9	49.0	48.3
Netherlands	4.9	9.7	7.1	49.3	66.1	74.4	12.2	27.1	49.9	43.2
Spain	5.2	17.5	22.9	51.6	72.7	72.2	. . .	27.5	58.5	56.5
Sweden	1.9	2.5	7.7	19.6	18.4	35.2	. . .	6.8	6.5	15.7
United Kingdom	5.0	10.0	8.2	39.7	57.2	60.7	17.6	24.5	40.8	43.5
United States	6.7	7.2	5.6	8.8	9.9	17.3	. . .	4.2	5.7	9.7
OECD Europe	4.7	9.2	10.3	. . .	. . .	. . .	. . .	31.5	52.8	. . .
Total OECD	4.9	7.3	7.6	. . .	. . .	. . .	. . .	26.6	33.7	. . .

[a] Unemployment in 1974–1979 and 1980–1989 is from OECD, Employment Outlook (1991), Table 2.7.
[b] Unemployment in 1995 is from OECD, Employment Outlook (1996), Table 1.3.
[c] Long-term unemployment in 1979 is from OECD, Employment Outlook (1984b), Table H; except for the OECD aggregate figures, which are averages for 1979 and 1980 from OECD, Employment Outlook (1991), Table 2.7.
[d] Long-term unemployment in 1989 is from OECD, Employment Outlook (1992a), Table N; except for the OECD aggregate figures that are from OECD, Employment Outlook (1991), Table 2.7.
[e] Long-term unemployment in 1995 is from OECD, Employment Outlook (1996), Table Q.
[f] Long-term unemployment in 1970 is from OECD, Employment Outlook (1983), Table 24.
[g] Except for year 1995, data refer to former West Germany only.

Section 3.1, in terms of an entry rate into unemployment λ and a mean duration of unemployment $1/[1 - F(\overline{w})]$. Given the wage distribution F, both the level and duration of unemployment are influenced by the reservation wage $\overline{w}$.

McCall theorized about how workers choose $\overline{w}$. He derived a Bellman equation for the reservation wage $\overline{w}$, above which all wage offers are accepted. For the present setting with firing probability λ, the reservation wage $\overline{w}$ satisfies

$$\frac{\overline{w} + \beta\lambda Q}{1 - \beta(1-\lambda)} = b + \beta Q,$$

where b is the level of unemployment compensation, β is a discount factor, and Q is the optimal value of the expected discounted income of an unemployed worker who is about to draw a wage offer. The worker accepts all wage offers above $\overline{w}$ and rejects all those below it. In turning down a wage offer, the worker preserves the opportunity to look for a better job. McCall thus showed how the reservation wage is influenced by the distributions F and λ, as well as by any unemployment compensation to which the unemployed worker might be entitled.

When coupled with the above equation for U, McCall's theory of $\overline{w}$ completes what Lucas called a "prototype (at least) of a theory of unemployment" (Lucas, 1987, p. 56). Lucas praised McCall's model for the way it invites criticism:

> in so criticizing McCall's model, we are . . . really thinking about what it is like to be unemployed. . . . Questioning a McCall worker is like having a conversation with an out-of-work friend: "Maybe you are setting your sights too high," or "Why did you quit your old job before you had a new one lined up?" This is real social science: an attempt to model, to *understand*, human behavior by visualizing the situations people find themselves in, the options they face and the pros and cons as they themselves see them. (Lucas, 1987, p. 57)

We seek conversations with two McCall workers: one who lives under Europe's generous unemployment compensation system and another his American clone who experiences identical shocks but confronts the opportunities offered by stingy unemployment compensation arrangements. We extend McCall's model to enable us to have these conversations.

At every moment in the basic McCall model, all employed workers are alike and all unemployed workers are alike. To explain the observations on European unemployment, Ljungqvist and Sargent (1998) extended the basic model to make employed and unemployed workers heterogeneous with respect both to their skills and to the unemployment compensation to which they are entitled. We use that heterogeneity to model how Europe's generous systems of unemployment compensation influence the level and the duration of unemployment.

3. EMPIRICAL PATTERNS TO BE LINKED

This section sketches some evidence about the structure of recent European unemployment and the relative generosity of European unemployment compensation. It then turns to evidence that we interpret as indicating that the environment confronting workers has become more turbulent in the last couple of decades, exposing them to **larger probable losses of valuable skills** on those occasions when their jobs terminate.

3.1. Decomposition of Unemployment

As equation (1) indicated, an unemployment rate can be analyzed in terms of an inflow rate and an average duration of unemployment. As summarized by Layard et al. (1991), the rise in European unemployment is caused mainly by an increase in the duration of unemployment, whereas the inflow rate has been roughly constant. This phenomenon is illustrated in Figure 2 for Great Britain [panel (b)], whereas the United States [panel (a)] shows no trend in either the average duration or the inflow rate. Layard et al. continue with the observation that the average duration of unemployment does not capture the huge variation in the length of spells of

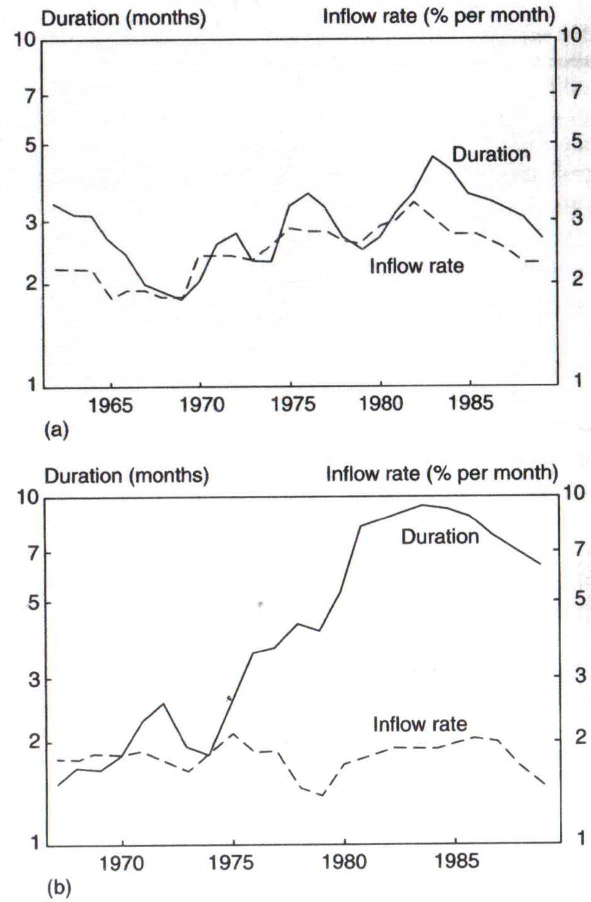

Figure 2. Inflow rates and duration of unemployment: (a) United States and (b) Great Britain, males. (Reproduction of Layard et al., fig. 3 [1991, p. 225].)

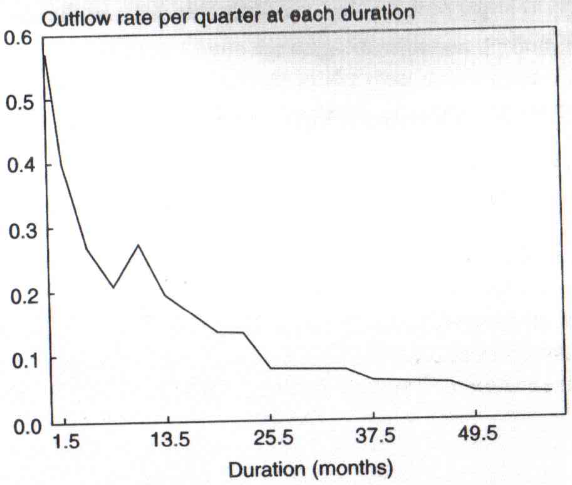

Figure 3. Outflow rates per quarter for different durations of unemployment: Great Britain, males, 1985. (Reproduction of Layard et al., fig. 4, panel c [1991, p. 226].)

unemployment. Figure 3 reproduces their data for the outflow rates for different durations of male unemployment in Great Britain in 1985. The outflow or "hazard" rate is the proportion of survivors of each duration that leave unemployment in the subsequent quarter. The figure shows starkly how the outflow rate in Great Britain is much lower at the longer durations.

3.2. Generosity of Unemployment Benefits

It is difficult to provide a summary measure of a country's "replacement rate," that is, the proportion of lost income from work that is replaced by unemployment compensation and related welfare benefits. The benefits come not only from different programs, such as housing benefits, but also depend on specific personal and family characteristics of the unemployed. The OECD has launched a project to gather relevant data and construct replacement rates comparable across countries. Martin (1996) reports the OECD's computations of the welfare benefits available to the average 40-year-old worker with a long employment. Table 2 shows net unemployment benefit replacement rates, depending on family status, after tax and housing benefits. The United States stands out in the table with hardly any benefits after the first year of unemployment, whereas the European countries have replacement rates around 70 percent even in the 5th year out of work.

3.3. Turbulence

It is a widely held notion that the economic environment has become more turbulent in the two last decades. OECD (1994, pp. 29–30) sums it up as follows:

> In the stable post–World War II economic environment, standards of living in most OECD countries grew rapidly, narrowing the gap with the area's highest per capita income country, the United States. The OECD area's terms of trade evolved favourably; trade and payments systems were progressively liberalised, without major problems; GDP and international trade grew strongly.
>
> In the 1970s, the economic environment became turbulent. The two oil price rises, in 1973/74 and 1979/80, imparted major terms-of-trade shocks, each of the order of 2 per cent of OECD-area GDP, and each sending large relative price changes through all OECD economies. Exchange rate became volatile after the breakdown of the Bretton Woods system of fixed exchange rates. Then there came, mainly in the 1980s, waves of financial-market liberalisation and product market deregulation which greatly enhanced the potential efficiency of OECD economies, and also accelerated the pace of change. All these developments challenged the capacity of economies and societies to adapt. At the same time, the need to adapt was heightened by pervasive technological change, especially as the new information technologies appeared; and by the trend towards globalisation.

Table 2. Net Unemployment Benefit Replacement Rates[a] in 1994 for Single-Earner Households by Duration Categories and Family Circumstances

	Single			With dependent spouse		
	1st year	2nd and 3rd years	4th and 5th years	1st year	2nd and 3rd years	4th and 5th years
Belgium	79	55	55	70	64	64
France	79	63	61	80	62	60
Germany	66	63	63	74	72	72
Netherlands	79	78	73	90	88	85
Spain	69	54	32	70	55	39
Sweden[b]	81	76	75	81	100	101
United Kingdom[b]	64	64	64	75	74	74
United States	34	9	9	38	14	14

Source: Martin (1996, table 2).

[a] Benefit entitlement on a net-of-tax and housing benefit basis as a percentage of net-of-tax earnings.

[b] Data for Sweden and the United Kingdom refer to 1995.

The sense of turbulence relevant for us must manifest itself in terms of greater volatility of workers' earnings. Gottschalk and Moffitt (1994) provide empirical evidence of such an increase. For the two periods 1970–1978 and 1979–1987, they summarized U.S. earnings distributions in ways that led them to conclude that both the "permanent" and "transitory" components of the distributions had spread out from one subperiod to the next. In particular, using data from the Michigan Panel Study on Income Dynamics (PSID), they computed an individual's average earnings for each subperiod to arrive at an estimate of the individual's permanent earnings. Figure 4a shows the distribution of those earnings in the two subperiods. They also computed the variance of an individual's income fluctuations, or transitory earnings, around his or her permanent earnings. The distribution of the standard deviations of transitory earnings in the two subperiods is depicted in Figure 4b. As can be seen, the dispersion of *both* permanent earnings and the standard deviations of transitory earnings increased in 1979–1987 compared to

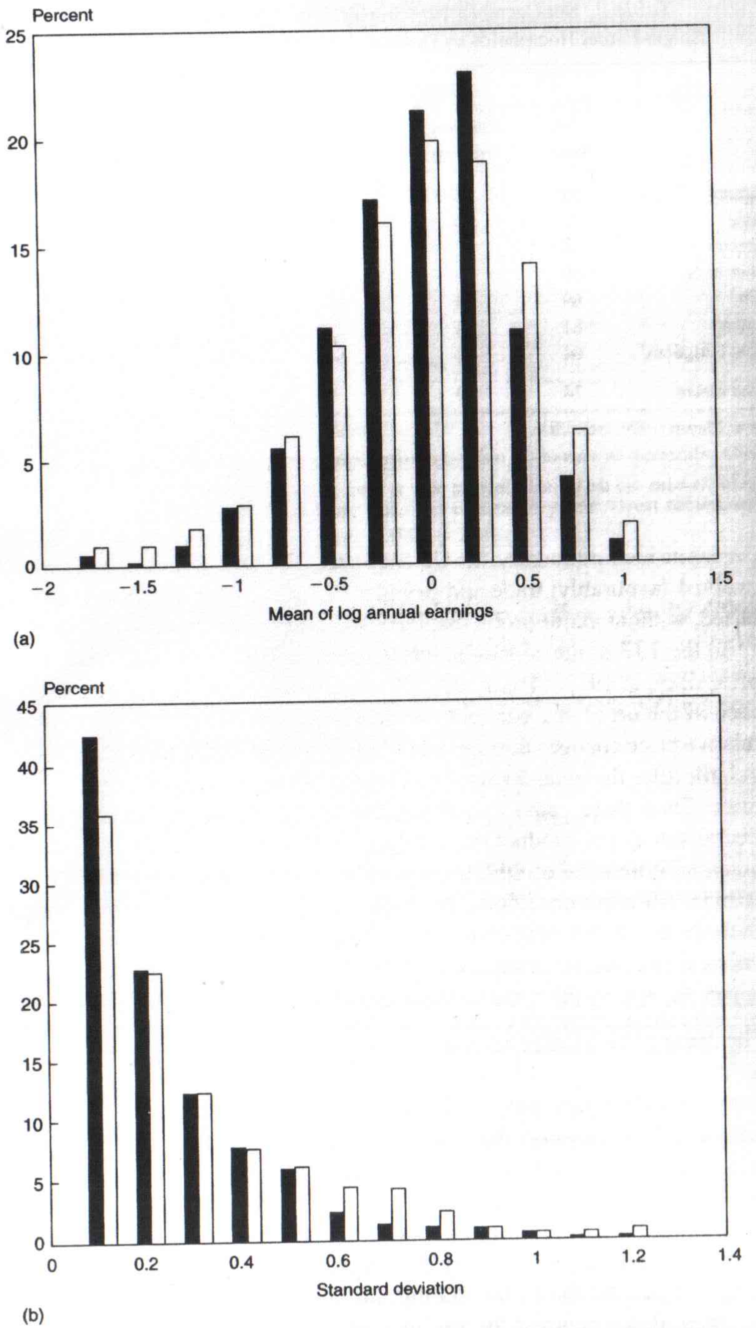

Figure 4. (a) Distribution of permanent earnings, 1970–1978 (black bars) and 1979–1987 (white bars). (b) Distribution of standard deviations of individuals' transitory earnings, 1970–1978 (black bars) and 1979–1987 (white bars). (Reproduction of Gottschalk and Moffitt, figs. 2 and 4 [1994].)

1970–1978. Gottschalk and Moffitt and their discussants (see Katz, 1994; Dickens, 1994) interpreted these statistics in terms of how the increase in the dispersion of earnings observed during the 1980s in the United States was accompanied by an increase in the intertemporal volatility of an individual's earnings.[4]

We want to interpret the volatility of earnings studied by Gottschalk and Moffitt partly in terms of the destruction of a worker's human capital that occurs at the time of a job termination. A study that provides evidence of that destruction in the United States is by Jacobson et al. (1993), who found that long-tenured displaced workers experienced large and enduring earnings losses. In their Pennsylvania sample from the 1980s, a displaced worker experienced the following typical pattern: a sharp drop in earnings in the quarter a job was left, followed by a rapid recovery during the next couple of years toward an eventual level of about 25 percent less than earned at the predisplacement job. Figure 5 reproduces Figure 1 from Jacobson et al., which dramatically displays the pattern by showing the disparate expected earnings patterns of long-tenured workers who were displaced in the first quarter of 1982 compared to workers who remained employed throughout the period.

Evidence in the style of Jacobson et al. is especially relevant to us because we model economic turbulence in terms of the risk of losing skills at the time of a layoff. The next section describes a search model of the labor market with such a skill technology and the assumption that unemployment benefits are determined by workers' past earnings. In Ljungqvist and Sargent (1998), we showed that our model of increased turbulence can produce outcomes for earnings processes that mimic the findings of both Gottschalk and Moffitt and Jacobson et al.[5] In this chapter, we take a more personal approach and study the life histories of two workers who are identical in all respects except for the institutions governing unemployment compensation under which they live (Section 5). In addition, simulations presented in Section 6 show that a generous replacement rate for unemployment makes the unemployment rate, the mean duration of unemployment, and the incidence of long-term unemployment very sensitive to the amount of economic turbulence.

4. A MULTISTATE MODEL OF A EUROPEAN McCALL WORKER

We have added three features to the basic McCall search model[6]:

1. In period $t+1$, an unemployed worker receives an offer drawn from c.d.f. F with a probability $\pi(s_t)$ that depends on a variable search intensity s_t chosen at time t at a cost $c(s_t)$.

4. More evidence was analyzed by Blundell and Preston (1998) and Meghir and Pistaferri (2001). From data on British households' consumption and income for 1968–1992, together with the restrictions implied by consumption-smoothing models, Blundell and Preston found "strong growth in transitory inequality toward the end of this period" as well as rising permanent components of income inequality. For U.S. data from the PSID, Meghir and Pistaferri found rising volatility of innovations for much of the period from 1969 to 1990 and somewhat of a decline late in their sample.

5. See Figures 14 and 15 of Ljungqvist and Sargent (1998).

6. Like McCall's model, ours assumes that the wage offer completely characterizes the job.

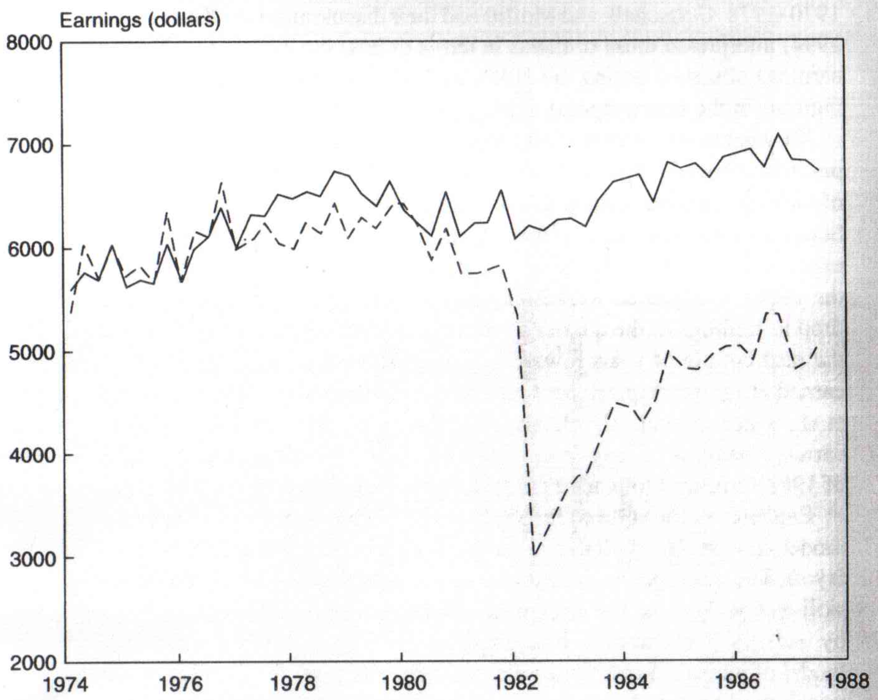

Figure 5. Quarterly earnings of high-attachment workers separating in the first quarter of 1982 and workers staying through 1986. The solid line refers to stayers, the dashed line, to separators. (Reproduction of Jacobson et al., fig. 1 [1993]. We have omitted the last observation of Jacobson et al. because it is based on too small a sample.)

2. The worker's earnings on a job are the product of his initial wage draw w and his level of skill h_t. Skill accumulates or depreciates stochastically at rates depending on whether the worker is employed or unemployed. In particular, we assume that work experience makes skills accumulate whereas unemployment makes them depreciate.
3. Unemployment compensation is based upon the unemployed worker's last earnings on a job.

To represent turbulence, we allow for the possibility that a worker instantaneously loses some skills at the time of being laid off. Such a loss reflects the fact that some skills are job specific and that those skills become obsolete especially quickly in times of industry restructuring. We capture economic turbulence in our analysis by changing the amount of instantaneous skill losses. A more turbulent economic environment in our model is tantamount to making workers face bigger risks of skill loss at times of layoff. Regardless of any such skill loss, laid-off workers are entitled to unemployment compensation as a fraction of their lost earnings.

4.1. Details of Environment

There is a continuum of workers with geometrically distributed life spans, indexed on the unit interval with births equaling deaths. An unemployed worker in period t chooses a search intensity $s_t \geq 0$ at a disutility $c(s_t)$ increasing in s_t. Search may or may not generate a wage offer in the next period. With probability $\pi(s_t)$, the unemployed worker receives one wage offer from the distribution $F(w) = \text{Prob}(w_{t+1} \leq w)$. With probability $1 - \pi(s_t)$, the worker receives no offer in period $t+1$. We assume $\pi(s_t) \in (0, 1)$, and that it is increasing in s_t. Accepting a wage offer w_{t+1} means that the worker earns that wage (per unit of skill) for each period he is alive, not laid off, and has not quit his job. The probability of being laid off at the beginning of a period is $\lambda \in (0, 1)$. In addition, all workers are subjected to a probability of $\alpha \in (0, 1)$ of dying between periods.

Employed and unemployed workers experience stochastic accumulation or deterioration of skills. There is a finite number of skill levels with transition probabilities from skill level h to h' denoted by $\mu_u(h, h')$ and $\mu_e(h, h')$ for an unemployed and an employed worker, respectively. That is, an unemployed worker with skill level h faces a probability $\mu_u(h, h')$ that his skill level at the beginning of the next period is h', contingent on not dying. Similarly, $\mu_e(h, h')$ is the probability that an employed worker with skill level h sees his skill level change to h' at the beginning of the next period, contingent on not dying and not being laid off. In the event of a layoff, the transition probability is given by $\mu_l(h, h')$. After this initial period of a layoff, the stochastic skill level of the unemployed worker is again governed by the transition probability $\mu_u(h, h')$. All newborn workers begin with the lowest skill level.

A worker observes his new skill level at the beginning of a period before deciding to accept a new wage offer, choose a search intensity, or quit a job. The objective of each worker is to maximize the expected value

$$E_t \sum_{i=0}^{\infty} \beta^i (1-\alpha)^i y_{t+i},$$

where E_t is the expectation operator conditioned on information at time t, β is the subjective discount factor, and $1 - \alpha$ is the probability of surviving between two consecutive periods; y_{t+i} is the worker's after-tax income from employment and unemployment compensation at time $t + i$ net of disutility of searching.[7]

Workers who were laid off are entitled to unemployment compensation benefits that are a function of their last earnings. Let $b(I)$ be the unemployment compensation to an unemployed worker whose last earnings were I. Unemployment compensation is terminated if the worker turns down a job offer with earnings that are deemed to be "suitable" by the government in view of that individual's past earnings. Let $I_g(I)$ be the government-determined "suitable earnings" of an

7. We have abstracted from the benefits of risk sharing that government policies can provide when capital markets are incomplete. Adding such considerations would modify but not change the flavor of our results.

unemployed worker whose last earnings were I. Newborn workers and workers who have quit their previous job are not entitled to unemployment compensation. Income from both employment and unemployment compensation are subject to a flat income tax of τ. The government policy functions $b(I)$ and $I_g(I)$ and the tax parameter τ must be set so that income taxes cover the expenditures on unemployment compensation in an equilibrium.

Let $V(w, h)$ be the value of the optimization problem for an employed worker with wage w and skill level h at the beginning of a period. The value associated with being unemployed and eligible for unemployment compensation benefits is given by $V_b(I, h)$, which is both a function of the unemployed worker's past earnings I and his current skill level h. In the case of an unemployed worker who is not entitled to unemployment compensation, the corresponding value is denoted by $V_0(h)$ and depends only on the worker's current skill level. The Bellman equations can then be written as follows:

$$V(w,h) = \max_{\text{accept,reject}} \left\{ (1-\tau)wh + (1-\alpha)\beta\left[(1-\lambda)\sum_{h'}\mu_e(h,h')V(w,h') \right.\right.$$
$$\left.\left. + \lambda \sum_{h'} \mu_l(h,h')V_b(wh,h')\right], V_0(h)\right\}, \tag{2}$$

$$V_b(I,h) = \max_s \left\{ -c(s) + (1-\tau)b(I) + (1-\alpha)\beta\sum_{h'}\mu_u(h,h') \right.$$
$$\left[[1-\pi(s)]V_b(I,h') + \pi(s)\left(\int_{w\geq I_g(I)/h'} V(w,h')dF(w) \right.\right.$$
$$+ \int_{w<I_g(I)/h'} \max_{\text{accept,reject}} \left\{ (1-\tau)wh' \right.$$
$$+ (1-\alpha)\beta\left[(1-\lambda)\sum_{h''}\mu_e(h',h'')V(w,h'') \right.$$
$$\left.\left.\left.\left.\left. + \lambda\sum_{h''}\mu_l(h',h'')V_b(wh',h'')\right], V_b(I,h')\right\} dF(w)\right)\right]\right\}, \tag{3}$$

$$V_0(h) = \max_s \left\{ -c(s) + (1-\alpha)\beta\sum_{h'}\mu_u(h,h')\left[[1-\pi(s)]V_0(h') \right.\right.$$
$$\left.\left. + \pi(s)\int V(w,h')dF(w)\right]\right\}. \tag{4}$$

Associated with the solution of equations (2)–(4) are two functions, $\bar{s}_b(I, h)$ and $\overline{w}_b(I, h)$, giving an optimal search intensity and a reservation wage of an unemployed worker with last earnings I and current skill level h, who is eligible for unemployment compensation benefits, and two functions, $\bar{s}_0(h)$ and $\overline{w}_0(h)$,

giving an optimal search intensity and a reservation wage of an unemployed worker with skill level h, who is not entitled to unemployment compensation. The reservation wage of an employed worker will be the same as for an unemployed worker without benefits, $\overline{w}_0(h)$, since anyone who quits his job is not eligible for unemployment compensation.

4.2. Stationary Equilibria

We will study stationary equilibria, or steady states, for our economy. A steady state is defined in a standard way, as a set of government policy parameters, optimal policies $[\bar{s}_0(h), \overline{w}_0(h), \bar{s}_b(I, h), \overline{w}_b(I, h)]$ and associated time-invariant employment and unemployment distributions and total unemployment compensation payments that satisfy workers' optimality conditions and the government's budget constraint. We compute a steady state as a fixed point in the tax rate τ. For a fixed tax rate τ, we solve the workers' optimization problem and use the implied search intensities and reservation wages to deduce stationary employment and unemployment distributions and compensation. A balanced government budget defines a fixed point in τ, which is associated with a stationary equilibrium.[8] After finding a stationary equilibrium, we compute various quantities such as GNP per capita, average productivity of employed workers, average skill level, average duration of unemployment, and measures of long-term unemployment.

4.3. Lakes and Streams

As with the basic McCall model described above, we can imagine the labor market as a set of lakes connected by inlet and outlet streams. Figure 6 depicts an example with two possible skill levels. The volume of water in each lake represents the number of people in a particular labor market state (e.g., employed, unemployed and having quit a previous job, unemployed and having been laid off from a previous job, unemployed because of having just entered the labor force), and the flows between lakes represent rates of hiring, firing, and quitting. The system is in a stationary equilibrium when all lake levels are constant over time, which means that inflows just balance outflows for each lake. The rates of inflow and outflow are evidently the critical determinants of the lake levels. The individual search model lends itself to becoming a model of these inflow and outflow rates if we simply reinterpret the probability of job acceptance as determining the *rate* of flow from a state of unemployment to a state of employment.

4.4. Skill Dynamics

Two sets of parameters mainly drive our results—those giving the skill technology and the unemployment compensation scheme.[9] There are twenty-one skill levels

8. The iterative procedure picks the lowest possible τ consistent with a stationary equilibrium. We choose to focus on this, the least distortionary, tax rate and ignore any higher tax rates that might be consistent with other steady states.

9. For a detailed discussion of all parameter values in our model, see Ljungqvist and Sargent (1998).

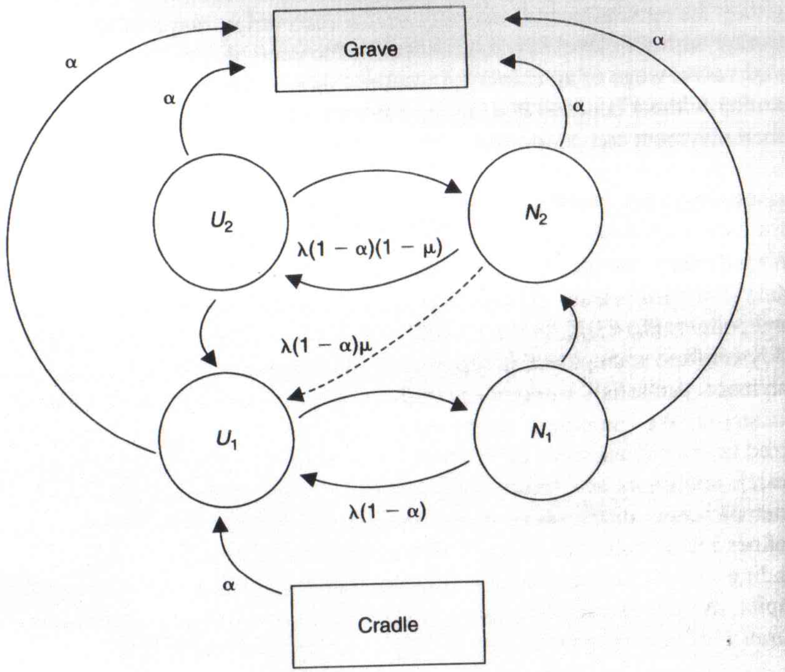

Figure 6. Employment flows and reservoirs in a model with birth/death probability α, layoff probability λ, quitting, and decisions to accept or refuse offers. Here U_1 and U_2 denote pools of unemployed workers of low and high human capital, respectively; N_1 and N_2 measure employed workers of low and high human capital, respectively. The dotted line flowing from the high-skill pool of employed people N_2 to the low-skill pool of unemployed people U_1 depicts the stochastic depreciation of skills that we use to represent turbulence; conditional on being laid off, the skilled worker's skill level drops from high to low with probaiblity μ. A flow of quitters has been omitted from the graph. Employed workers who gain human capital may choose to quit to seek better-paying jobs.

in our model that evenly span the range [1, 2]. Newborn workers are endowed with the lowest skill level, equal to one, and work experience can result at most in twice that level of skill. The evolution of skills while employed is as follows. After each 2-week period of employment not followed by a layoff, the worker has a one in ten chance to increase skills by one level; otherwise, the skill level remains unchanged. Employed workers who have reached the highest skill level retain those skills until becoming unemployed. It will take a worker who is continuously employed, on average, about 7 years and 8 months to reach the highest skill level. We assume the stochastic depreciation of skills during unemployment to be twice as fast as the accumulation of skills. That is, after each 2-week period of unemployment, there is a one in five risk that the worker's skills decrease by one level; otherwise, they remain unchanged. Once the lowest skill level is reached through depreciation, the worker remains at that level until becoming employed.

In a period of being laid off, we assume that the worker draws a new skill level from one of the distributions in Figure 7. The range of each distribution

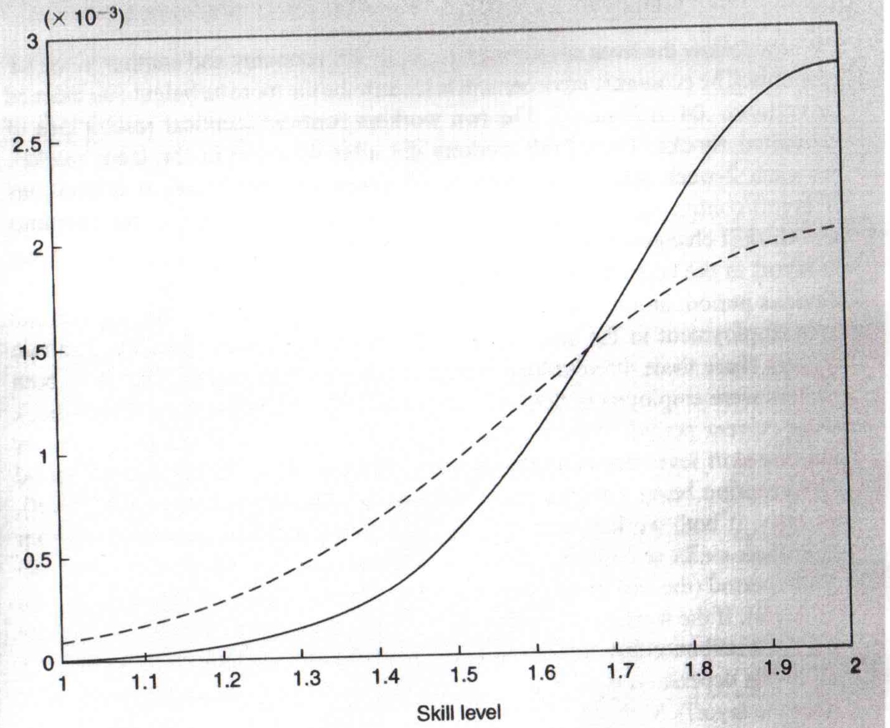

Figure 7. The probability distribution of a worker's skills immediately after a layoff. The range starts at the lowest skill level of 1 and ends at the worker's skill level before the layoff. The graph is drawn for a worker who had attained the highest skill level of 2 before the layoff. The solid line and dashed line refer to different degrees of economic turbulence indexed by variance .02 and .04, respectively.

starts at the lowest possible skill level equal to one, and ends at the worker's skill level before the layoff. In other words, the worker stands to lose some skills immediately; occasionally workers draw a significantly lower skill level, one from the left-hand tail of the distribution. The two distributions in Figure 7 refer to two different degrees of economic turbulence. The distribution indexed by variance .04 corresponds to a more turbulent economic environment since there is a higher probability for large skill losses; that is, the left-hand tail is fatter compared to the distribution indexed by variance .02.

Concerning the unemployment compensation scheme, we examine the outcome for two economies, one with unemployment insurance and one without. The economy with unemployment insurance is called the welfare state (WS), and has both a 70 percent replacement rate and a 70 percent "suitable earnings" criterion. That is, laid-off workers receive unemployment benefits equal to 70 percent of lost earnings as long as they do not turn down jobs with earnings greater than or equal to those benefits. The economy with no unemployment insurance is called the laissez-faire (LF) economy.

5. "CONVERSATIONS" WITH TWO WORKERS

We now follow the lives of one worker in the WS economy and another in the LF economy. The economic environment is taken to be the more turbulent one indexed by variance .04 in Figure 7. The two workers confront identical realizations of individual shocks. Thus, both workers die after 40 years in the labor market. For each 2-week period during those 40 years, we draw random realizations of layoff/continuing employment, conditional on employment in the previous period; skill changes (bounded by the permissible skill range [1, 2]), conditional on layoff in the current period; continuing employment or unemployment in the previous period; and a search outcome with or without a wage offer, conditional on unemployment in the previous period and chosen search intensity. The two workers share these 40-year-long sequences of potential shocks. That is, if both workers were employed in the previous period, they share the same layoff shock in the current period. If they are not laid off, both either retain their skills or gain one skill level depending on another common shock in the current period (the exception being a worker who has already reached the highest skill level). Similarly, if both workers were unemployed in the previous period, both either retain their skills or lose one skill level depending on a common shock in the current period (the exception being a worker who has already reached the lowest skill level). If the workers are laid off in the same period, they face the same draw from the distribution indexed by variance .04 in Figure 7 but their realized absolute skill levels depend on their particular right-hand end points (i.e., skill levels just before the layoff). Moreover, if the two workers find jobs in the same period, they will be offered the same wage per unit of skill. The likelihood of generating a wage offer will naturally depend on their search intensities chosen in the previous period.

Since our two workers share the same sequences of potential shocks, they would also experience the same lives if they made the same decisions at all points in time. Our assumption of maximizing behavior implies that they *would* make the same decisions if they lived in the same environment, in particular, under the same tax and benefit rules. But the two workers are unlikely to make identical decisions because they live with different institutional arrangements in the WS economy and the LF economy. Figures 8a and b show what occurs for our particular random draw of shocks. It happens that the two workers do actually make the same decisions during the first $27\frac{1}{2}$ years in the labor force. After entering the labor market, they both find and accept a job after 3 months of unemployment. However, their first job lasts less than a year and they experience another spell of unemployment. This time the worker in the WS economy receives unemployment compensation equal to 70 percent of his lost earnings (not shown in Figure 8, which only depicts labor earnings). The workers' second job lasts 4 years and they accumulate considerable skills before being laid off again and thereby losing some of these skills. Their third job has a very attractive wage per unit of skill and, in a little more than 6 years, they have attained the highest skill level and their labor income is at the top of the earnings distribution.[10]

10. Wages per unit of skill are confined to the unit interval and the highest skill level is equal to two, which means that maximum earnings are two.

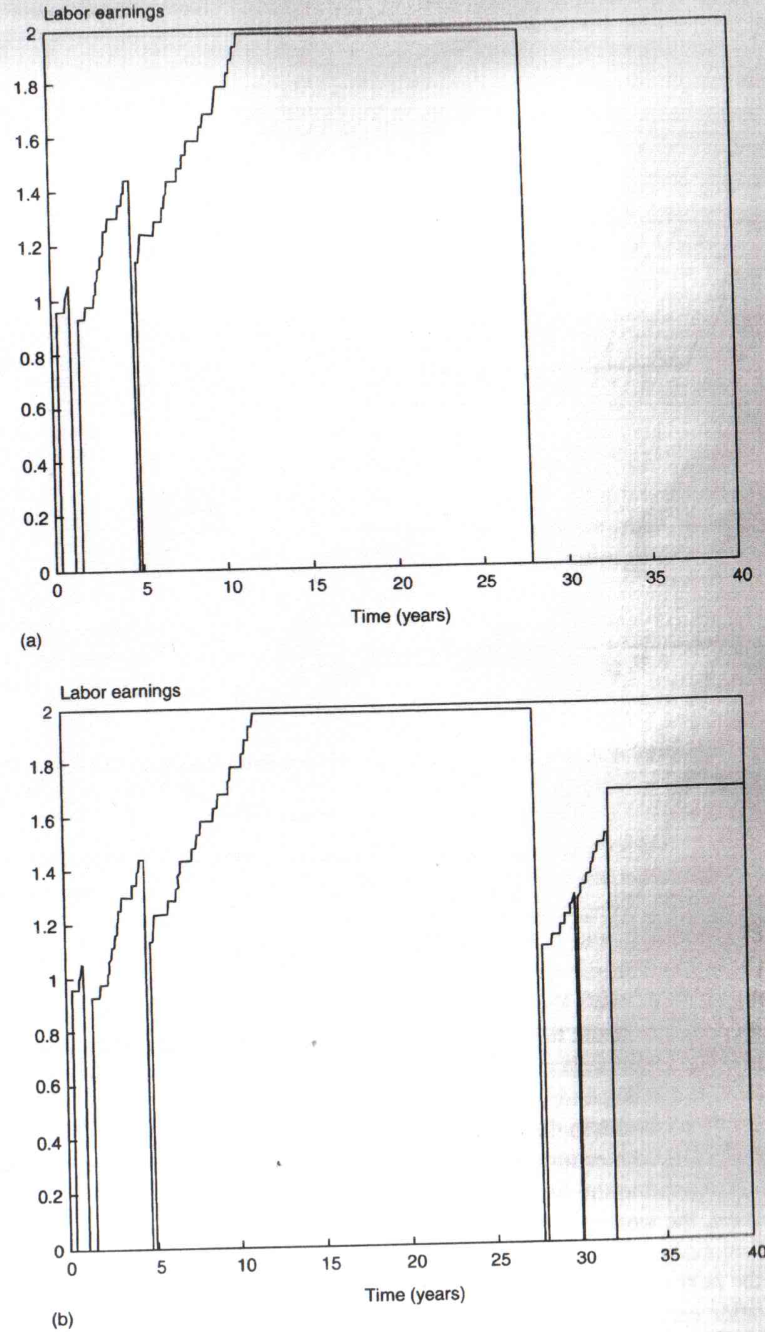

Figure 8. (a) Simulated labor earnings of a worker in the WS economy. (b) Simulated labor earnings of a worker in the LF economy.

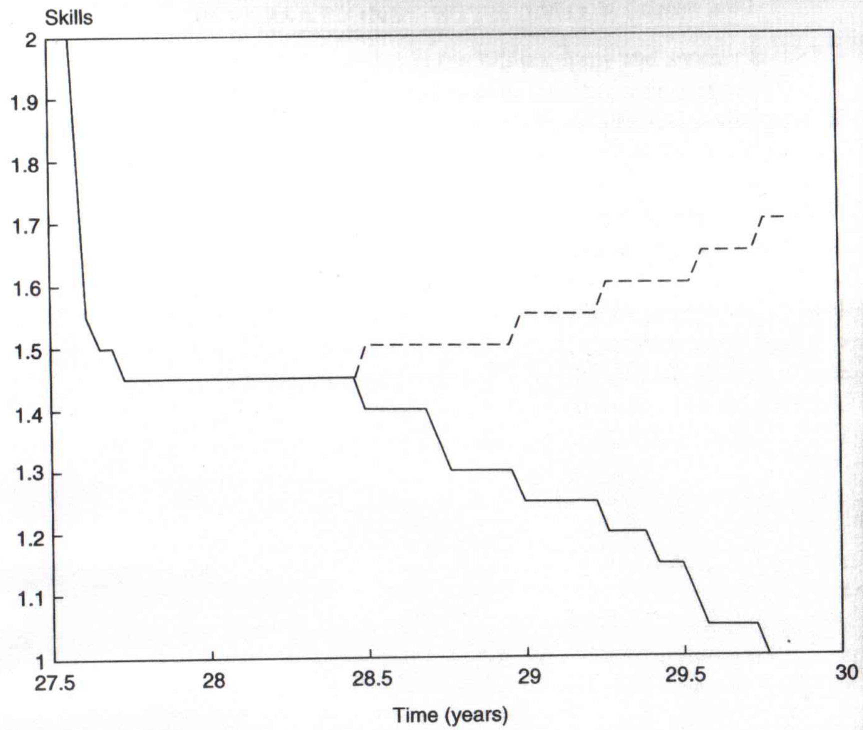

Figure 9. Simulated skills of a worker in the WS economy (solid line) and one in the LF economy (dashed line).

When the two workers are laid off from their long-tenure job in their 27th year in the labor market, their fates diverge dramatically in Figure 8. The worker in the WS economy never again posts any labor earnings, whereas the worker in the LF economy returns to work after 4 months of unemployment, though at substantially lower earnings. The question is, what goes wrong in the welfare state regime in that unfortunate 27th year? Figure 9 reveals that the workers experience a large loss (about 25%) of skills at the time of the layoff. A year after the layoff, the worker in the LF economy starts to rebuild skills in his new job, whereas the unemployed worker in the WS economy continues losing skills. A factor contributing to the inability of the worker in the WS economy to find an acceptable job can be found in Figure 10. The worker sets much higher "reservation earnings" for an acceptable job as compared to the worker in the LF economy. Given a replacement rate of 70 percent, the worker in the WS economy is more choosy than his colleague in the LF economy.

In the next couple of years, the worker in the WS economy starts lowering his reservation earnings in Figure 10, so it might seem surprising that he continues to have trouble finding a job. But the reservation earnings are set in relation to the unemployed worker's skills, which are also depreciating over time. It is therefore more informative to focus on the "reservation wage" per unit of skill in Figure 11.

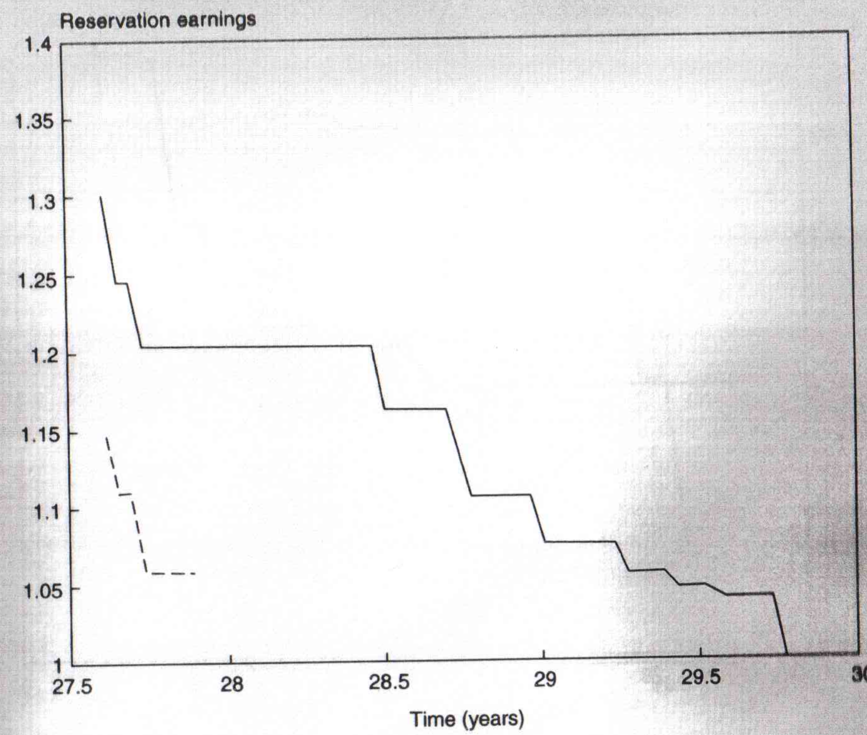

Figure 10. Simulated reservation earnings of a worker in the WS economy (solid line) and one in the LF economy (dashed line).

As can be seen, the worker in the WS economy is not becoming less choosy over time but *more*. The unemployed worker demands higher and higher reservation wages per unit of skill before being willing to surrender benefits that amount to 70 percent of past earnings. In other words, the worker is looking for a better and better "match" in the labor market, or wage per unit of skill, to compensate for his depreciating skills. The generous unemployment benefits make him compare any potential job with his past high earnings. Of course, the worker in our model is well aware of the low probability of finding such high wage offers, so it becomes rational for him to invest less in job search. Figure 12 shows a falling search intensity over time for the worker in the WS economy. After about 2 years of unemployment and fruitless job search, the worker becomes totally disillusioned and withdraws from labor market participation by setting his search intensity equal to zero (but he continues to receive benefits in our model).

6. AGGREGATE OUTCOMES

The simulations of two workers' lives illustrate the economic forces at work in our model. We can gain further insights by exploring the aggregate implications of alternative degrees of economic turbulence. Table 3 reports the steady states for the

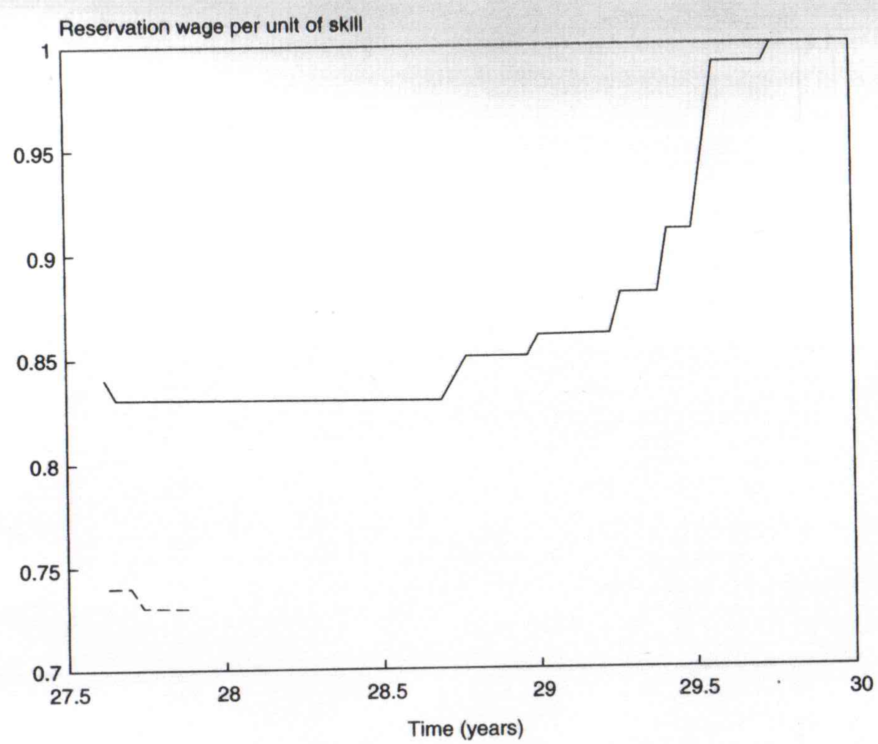

Figure 11. Simulated reservation wage per unit of skill of a worker in the WS economy (solid line) and of one in the LF economy (dashed line).

WS economy and the LF economy when turbulence is indexed by variance .02 and .04, respectively. The unemployment responds to increased economic turbulence in strikingly different ways in the two economies. When moving from low to high turbulence, the unemployment rate remains roughly constant in the LF economy but doubles in the WS economy. This outcome is consistent with our theory that increased economic turbulence in the 1980s contributed to high unemployment in the European welfare states, while leaving the U.S. unemployment rate unchanged, as in Table 1. Moreover, a decomposition of our artificial unemployment data into inflow rates and average duration of unemployment spells produces the same pattern as in Figure 2, provided that we once again let the United States approximate a LF economy and Great Britain represent a WS economy. In our analysis, the inflow rate remains practically constant across different degrees of economic turbulence because we keep the layoff rate λ unchanged. The parameter λ is chosen so that the monthly layoff rate is just above 1.8 percent. According to Table 3, the average duration of unemployment remains around $2\frac{1}{2}$ months in the LF economy for both degrees of economic turbulence. In contrast, the most turbulent economic environment produces an average duration of about 8 months in the WS economy, which is significantly higher than the 3 months in less turbulent times.

The worse employment performance of the WS economy arises from the increasing incidence of long-term unemployment. The fractions of long-term

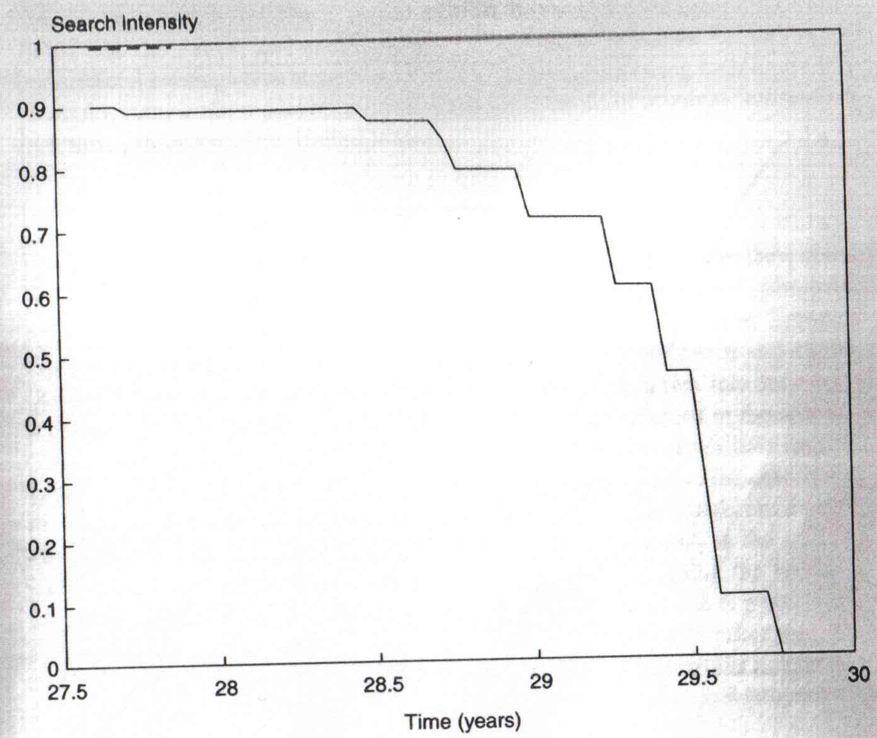

Figure 12. Simulated search intensity of a worker in the WS economy (solid line) and of one in the LF economy (dashed line).

Table 3. Equilibrium Outcomes for the WS Economy and the LF Economy with Different Degrees of Economic Turbulence

	Degree of economic turbulence			
	.02		*.04*	
	WS	*LF*	*WS*	*LF*
Tax rate (%)	3.88	n.a.	11.69	n.a.
Unemployment rate (%)	7.13	5.81	14.87	5.73
Average duration of unemployment (weeks)	13.7	10.6	31.8	10.7
Percentage of unemployed at a point in time with spells so far $\geq$ 6 months	18.2	8.2	63.1	8.5
Percentage of unemployed at a point in time with spells so far $\geq$ 12 months	5.8	0.6	55.6	0.6

unemployed explode in the WS economy when economic turbulence increases in Table 3. The percentage of currently unemployed workers with spells to date of 6 months or more rises from 18.2 to 63.1 percent. Concerning the percentage of unemployed workers with spells to date of 1 year or more, we find the corresponding increase in the WS economy to be from 5.8 to 55.6 percent. In the LF

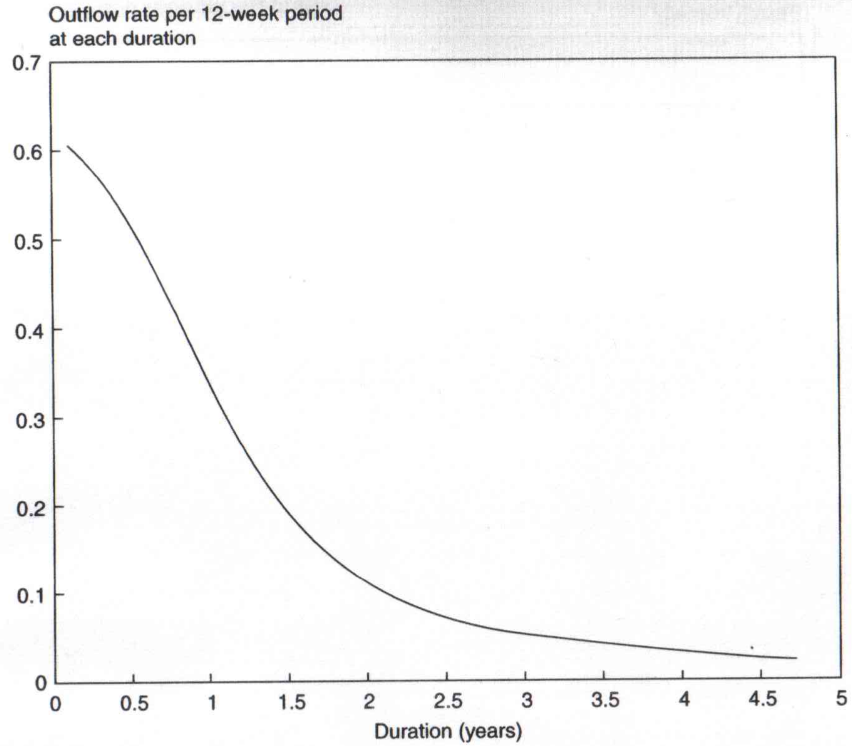

Figure 13. Outflow rates from unemployment per 12-week period at each duration in the WS economy with economic turbulence indexed by variance of .04.

economy, the small numbers of long-term unemployed stay virtually unchanged in response to increased economic turbulence.

The problem of long-term unemployment in the WS economy can also be studied in terms of hazard rates. Given the highest degree of economic turbulence indexed by variance .04, Figure 13 depicts the outflow rate from unemployment for the WS economy. This figure corresponds to our Figure 3, which we borrowed from Layard et al. (1991). Figure 13 from our artificial economy does a good job of emulating the pattern in the Layard et al. figure. Most unemployed workers leave unemployment during the first year of a spell. Thereafter, a significantly lower outflow rate tends to produce very long unemployment spells for the remaining unemployed.

We conclude that moving from a turbulence indexed by variance .02 to .04 can account quite well for the unemployment experience of Europe (the WS economy) and the United States (the LF economy) in the decades before and after 1980, respectively. The question then becomes what the empirical support is for our parameterization of the degree of economic turbulence. Since there are no data on human capital losses at layoffs, we will have to rely on indirect evidence such as observations on labor earnings. As mentioned above, we have shown earlier that our parameterization does in fact produce outcomes for earnings processes that mimic studies in the United States of both increased turbulence between the 1970s and the 1980s, and earnings losses of displaced workers.[11] If anything, our artificial earnings data suggest that the mechanism generating high long-term unemployment in our model operates at much lower levels of economic turbulence than those observed in the United States.

7. CONCLUSIONS AND EXTENSIONS

Having been encouraged by the way our model matches some of the facts about European unemployment, we are now refining it to capture more (see Ljungqvist and Sargent, 2002). In particular, we want to understand: (1) how Europe's unemployment was actually *lower* than America's during the 1950s and 1960s; and (2) how it is *older* workers who are now especially drawn into long-term unemployment in Europe. To understand these facts, we proceed in the spirit of Lucas's conversation with a McCall worker and add some more realistic features to the worker's environment. First, we add a worker's age as part of the description of his state. To control the dimension of the state, we add a small number of discrete ages and posit an exogenous stochastic aging process.[12] Second, in the spirit of Ljungqvist and Sargent (1995), instead of being constant during the worker's tenure on a job, we posit that the wage process while employed is a stochastic one. Stochastic "job reclassifications" confront the employed worker with the decision of staying or quitting. Third, we impose a tax on job destruction, a feature that several writers have emphasized in discussions of European unemployment.[13] These three features are overlaid on the model described above.

The interaction of a stochastic on-the-job wage with layoff costs is the key to explaining how unemployment was lower in Europe in the less turbulent environment of the 1950s and 1960s. The model predicts that Europe (modeled as having high unemployment compensation and a high job destruction tax) had a lower unemployment rate than a laissez faire country would have had in that period: With low turbulence, the model predicts that Europe would have lower job destruction rates and longer job tenures than would a country under laissez faire. That lower unemployment might have been purchased at an efficiency cost by making workers stay too long in jobs that had gone sour. An increase in turbulence in the extended model has broader effects than those analyzed in this chapter, prompting older workers especially to choose extended periods of unemployment. Thus, we expect to gain further insights from our extended McCall model.

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11. See Ljungqvist and Sargent (1998) for details.

12. The additional dimension of age adds lakes to the counterpart of Figure 6.

13. See Ljungqvist (2001) for a critical evaluation of how layoff costs work in several models of the labor market.

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Comments on Ljungqvist and Sargent

OLIVIER J. BLANCHARD

Discussions in a festschrift are like Japanese haikus. They must follow strict rules. In particular, they must have three parts (although—in contrast to haikus, and perhaps not for the best—each part can have more than five or seven syllables): The first part must show how the paper being discussed derives from the seminal work of the honoree. The second must argue that the paper being discussed shows how fruitful the approach has been. The third, which is required to establish the credibility of the first two, must pick a small bone of contention. I find all three very easy to achieve in this case.

1. ON THE GENERAL THEME AND THE FILIATION

The proposition that explaining the evolution of unemployment at anything lower than business cycle frequencies requires looking at shocks, institutions, and their interactions is a theme that I have made mine over the past few years. But it is a theme directly traceable to Ned's *Structural Slumps* (Phelps, 1994).

In that book, Ned took issue with the then prevailing Keynesian explanations for European unemployment. He argued that a model that ignored nominal rigidities could actually go a long way in explaining what had happened. He emphasized the role of shocks, insisting in particular on the role of real interest rates on both the demand and the supply of goods. He emphasized the roles of labor and goods market imperfections and of labor market institutions in creating and amplifying the effects of shocks on output and unemployment.

As a combatant initially on the opposite side, and one involved in many (intellectual) skirmishes with Ned over the years, I would submit that he has won the war. With the passage of time and the accumulation of research, viewing the evolution of European unemployment as largely an equilibrium phenomenon—as movements in the natural rate, or as Phelps calls it, the structural rate of unemployment, rather than as movements of the actual rate away from the natural rate—appears increasingly plausible. Movements in aggregate demand surely played a role in affecting the timing of the increase in unemployment, but the basic forces for the ups and the more recent downs must be found elsewhere.

Ned has not won all the battles. The set of relevant shocks, and the relevant market imperfections, may not be exactly those he relied on in *Structural Slumps*.

Whether fiscal policy has played the prominent role attributed to it in his analysis appears doubtful. Whether movements in markups reflect profit maximization by firms investing in consumers and how much changes in the real interest rate can affect the markup are still highly contentious issues. Whether the determination of real wages is best explained by an efficiency wage model, or by the type of bargaining captured in flow/matching models, or by models of collective bargaining is also far from established. Still, one finds many Phelpsian themes in current research. Take for example two of the themes of the Ljungqvist and Sargent chapter (LS in what follows): the description of the labor market as a decentralized market with search, a vision first articulated in the "Phelps volume" (1970); and hysteresis, the lasting effects of the loss of human capital coming from being unemployed, a theme first developed in Phelps's 1972 book. The legacy is impressive.

2. ON THE SPECIFIC MECHANISM IN LJUNGQVIST AND SARGENT

The notion that evolutions of unemployment across European countries over the last 30 years are best explained by the interaction of shocks and institutions is an appealing one. It offers the potential for reconciling largely similar shocks and mostly stable labor market institutions with the heterogeneity of unemployment experiences across countries.

In that context, the story developed by LS, in their chapter in this volume and in the work on which they built, is extremely appealing: Europe had institutions designed for quiet times. Times have changed, becoming more turbulent, requiring faster and higher reallocation of resources over time. The old institutions now stand in the way; in particular they are generating higher unemployment.

The story sounds highly plausible. It is yet another incarnation of the old trade-off between distribution and efficiency, between the welfare state and output maximization. Tell the story to noneconomists, to business people, and they will not only understand it, but also nod in approval.

The model itself is splendid and extremely rich in its implications. If anybody wanted proof that the stochastic dynamic programming methods introduced and developed by Sargent and others over the last two decades constitute a marvelous tool, this chapter provides it.

It allows for a smooth integration of a rich microeconomic story—the stories of the unemployed—and its macroeconomic implications: longer duration and a higher unemployment rate. LS are right to use the term "conversations": Some of the realized paths followed by the unemployed in their model sound like stories straight out of Studs Terkel's oral history of the Great Depression (Terkel, 1970). How the unemployed look for jobs, how some of them have bad luck, how they lose heart and give up searching, and how some of them, in the end, become unemployable.

Moreover, the value is clearly more than just in the story telling. Much is learned from calibration, from finding the assumptions and the parameters that give rise to the right stories. More importantly, the microtexture is rich enough to be confronted

directly with microeconomic data. While LS do not do it, it is easy to see how one could take this model to panel data on workers and see how it fits. We have the data sets to do so, and I am sure it will soon be done.

3. WHY I REMAIN SKEPTICAL: TURBULENCE

At the center of the LS story is an increase in turbulence. Again, a priori, this seems very plausible. After all, we all know how globalization, financial market deregulation, the dictatorship of pension funds, and higher product market competition are all forcing firms to act more quickly, discontinue old product lines, reallocate production across countries, and so on.

However, there is a catch: We may all know it, but the data just do not show it. . . .

This puzzle showed up early on, when European unemployment was just rising in the late 1970s. Increased turbulence already seemed to be a plausible candidate. But it turned out that the measures of reallocation we could construct, typically measures based on the standard deviation of rates of change of employment, either across sectors or across regions, showed no trend increase. The evidence as of the early 1980s is well summarized in Table 16-15 in Layard and Johnson (1986). That table gives measures by industry or by region for a number of countries: Half of the standard deviations are higher in 1979 than they were in 1960 and half are lower. In all cases, the changes are small. I could not locate a full update of this table for the 1980s and 1990s, but the series I have seen for a few countries yield the same conclusion: no apparent increase.

One may reasonably argue that these measures are too raw. Perhaps, the increase in reallocation is taking place mostly within industries or regions, rather than across them. In that respect, measures of job flows based on plant-level data along the lines of the work by Davis et al. (1996) are clearly preferable. The problem is that they typically do not go back far enough in time. But to the extent that they do, they also show little sign of increased turbulence.

Figure 1, for the United States, is based on the data constructed by Davis et al. (1996) for the period 1972 to 1993 (and downloaded from their web site). The lower line shows the evolution of job destruction (the sum of all employment changes at plants with decreasing employment divided by total employment); the upper line shows the evolution of job reallocation, defined as the sum of job destruction and job creation. If anything, the two lines appear to decline over time.

Figure 2 puts together evidence for France, based on two studies, one by Nocke (1994) for data from 1985 to 1990 and the other by Duhautois (1999) for data from 1990 to 1996. (The juxtaposition of the two series, constructed using slightly different data and methodologies, implies that there may be an artificial break in the series between 1990 and 1991.) The two lines are defined in the same way as in Figure 1. The conclusion is the same as for the United States: At least starting from when data are available, namely, 1985, there is no evidence of an increase in turbulence.

I have focused on turbulence because this is how the LS chapter sells itself. But the specific mechanism in the model is actually a bit different. It is better described

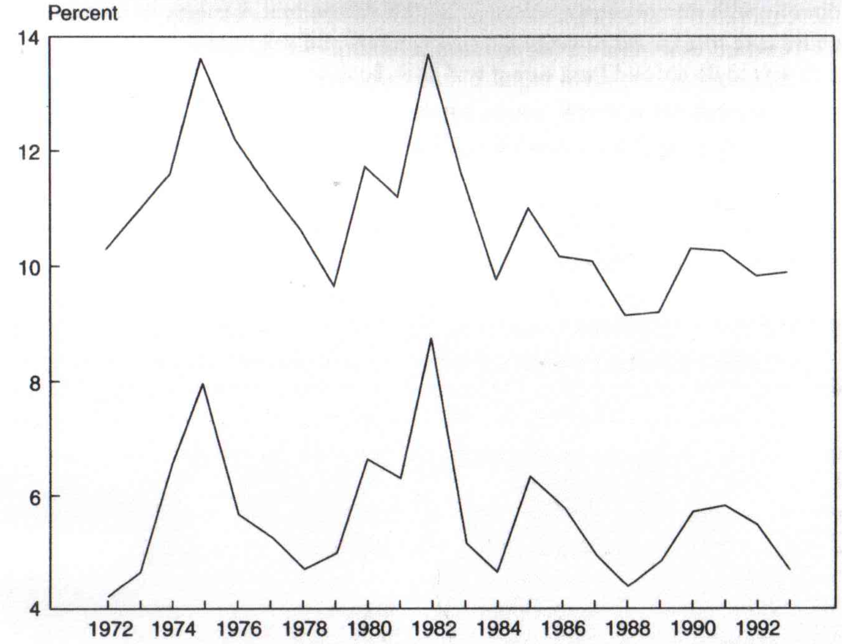

Figure 1. Job destruction and job reallocation, United States: Averages of quarterly rates, 1973 to 1993 (Davis et al., 1996).

as an increase in on-the-job learning and—more importantly for the results—an increase in off-the-job forgetting (the loss of skills by the unemployed). What is central to the results is the fact that when a worker becomes unemployed, the wage he can hope to get is now substantially lower than the wage he had in his previous job. Because unemployment benefits are indexed to the wage he received, this leads the worker to choose a high reservation wage relative to the distribution of wages he now faces. The larger the drop between the old wage and the new mean wage, the longer the unemployment duration, the higher the aggregate unemployment rate.

Turbulence can indeed plausibly generate a larger gap between the old and the new mean wage. But so can many other factors, which may or may not be directly related to turbulence. For example, stronger learning by doing, and so a steeper increase in the marginal product of a worker on a given job, will have the same effect, as will a steeper wage profile relative to the marginal product profile, reflecting higher bonding by workers. All these mechanisms can lead to a larger gap between the wage in the last job and the mean of the distribution faced by the unemployed worker, and so to the results in the chapter.

All of these explanations have one thing in common. They should be reflected in a steeper wage profile as a function of time on a job; and, here, the evidence—at least the evidence that I know of—is far from supportive. In France, for example, a study by Kramarz et al. (1996), which estimates Mincerian wage equations for 1986 and 1992, finds a significant reduction in the effect of time on the job on the

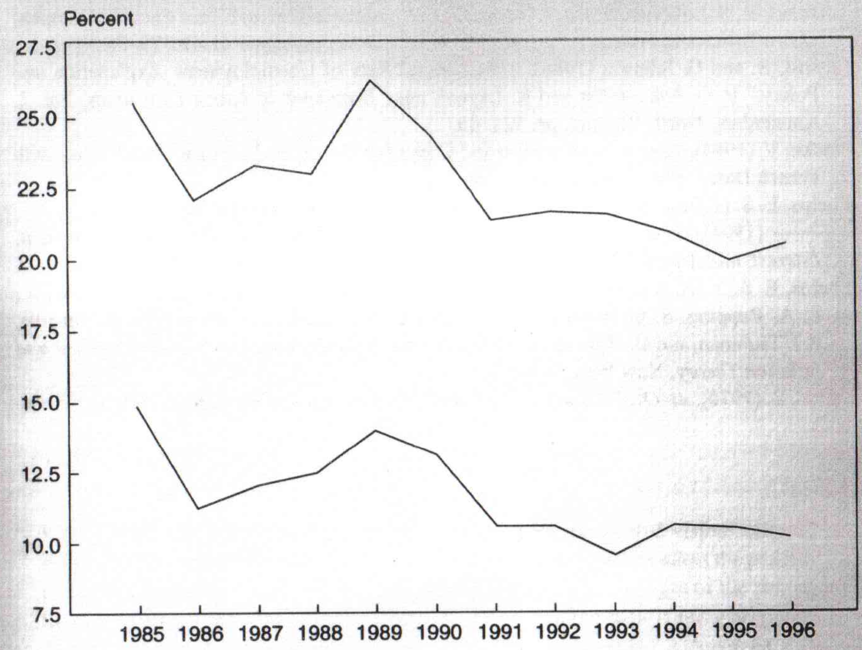

Figure 2. Job destruction and job reallocation, France: Annual rates, 1985 to 1996 (break in 1990–1991).

wage between the two dates. Interestingly, the reduction appears to hold across skill levels. The years 1986 and 1992 may be too close in time for us to draw strong conclusions about trends. But, at a minimum, the results do not appear very supportive of that central component of the LS story.

So where do we stand? Maybe our gut feelings are right: There is more turbulence, and the problem is with our measures, not with the facts. Maybe the story needs to be changed a bit. My own take on this is that European labor market institutions indeed lead to much longer unemployment duration and lower flows than in the United States, even at a given rate of unemployment. In that context, the same adverse shocks lead to very different individual unemployment experiences, along the lines of the chapter. Durations can become so long in Europe as to lead the long-term unemployed to drop out altogether. The story is a bit different from that of LS. But it is in the same spirit, and the tools they have developed can prove very useful there as well.

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