Wage Growth, Search and Experience: Theory and Evidence

[JOB MARKET PAPER]

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Abstract

The typical early career of a male highschool graduate in the US is characterized by significant wage growth and high mobility. Frequently, job changes are associated with large wage increases, and overall, wage growth between jobs accounts for a third of the worker's entire wage growth. Prompted by this observation, this paper asks the question, how much of the worker wage growth and welfare is due to search on-the-job and how much is due to the accumulation of experience while working. In order to answer the question, I construct a structural dynamic search model in which utility maximizing workers gain experience by working. The model parameters are estimated using the employment and wage data for a sample of young male highschool graduates from the National Longitudinal Survey of Youth (NLSY). The main finding is that the contribution of search on-the-job to a worker's welfare is roughly four times less than the contribution of experience. The structural model allows the analysis of the impact of this finding on the design of labor market policies. In particular, the optimal level of the unemployment benefit is higher in environments in which the relative contribution of search on-the-job to workers' earnings is small.

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1 Introduction

The typical early career of a male high school graduate in the US is characterized by significant wage growth and high mobility. In a recent survey, Rubinstein and Weiss (2004), provide ample evidence for this stylized fact using cross section data as well as longitudinal data. Using a sample of male high school workers from the National Longitudinal Survey of Youth (NLSY), I find that the mean real wage per hour increases from 5.17 in the first year of market experience to 6.85 after the first eight years (see Figure 3.2.5.). The average wage growth rate is 4.1 percent per year, it is higher during the first four years of market experience (5%) and then slows (3% in the next four years). Also, mobility (both between employment and unemployment as well as between jobs) is decreasing over the eight year period (see Figures 3.2.1.a., 3.2.2. and 3.2.3.).

These observations motivated a fruitful research agenda for the last few decades, directed at explaining wage growth and career choices of young workers. Although providing a full account of these contributions is beyond the scope of this paper, it is important to list a few theories, which explain, in different ways, the increasing pattern of wages over the life cycle. The human capital theory, which dates back to the models of Becker (1975) and Ben-Porath (1967), explains this fact as the outcome of investment in human capital by the workers, which increases their productivity over time. Labor search models in the tradition of Burdett (1978) have been offered as an alternative to deal with market frictions. In these models, workers receive random offers and choose to accept or reject them. This continuous process of sampling better and better offers over time triggers wage growth.[1] When search is combined with learning, it is possible to relate the increase in wages to aspects of job tenure and seniority. In learning models, employers continuously update information about workers, which leads to promotion for the best workers. Thus wage growth is explained by the arrival of new information as opposed to worker's actions or the arrival of new offers.[2] Finally, related to the latter, the contract theory provides yet another story capable of generating an increasing life cycle wage profile. There, in the presence of unobservable work effort, employers provide the optimal incentive scheme for the workers by paying them less than their productivity at the beginning of their tenure and more towards the end of their tenure.[3]

This paper focuses on two of the post-schooling sources of wage growth, namely, search on-the-job and accumulation of experience. It asks the question, how much of the worker's

[1] See Mortensen (1986) for a survey of this literature.
[2] See Jovanovics (1979a, 1979b) or Holmstrom (1999).
[3] See Lazear (1976) for one of the first models of this kind.

wage growth as well as wealth throughout his early career can be attributed to each source.

Evidence from the NLSY sample shows that, on average, wage growth on the job accounts for about 68% of a worker's overall wage growth during the first eight years of market experience. The rest is accounted for by wage growth between jobs.[4] While search on-the-job is the main driving source behind the growth of wages between jobs, that fact is not sufficient to disentangle the relative contribution of the two forces. These two forces are deeply entwined because both the accumulation of experience and search on-the-job affect worker mobility (in and out of unemployment and from job to job), which in turn affects wage growth and worker welfare.

To dig deeper into this decomposition, I construct a dynamic model in which a representative worker accumulates experience while working. An individual's wage is the product of his accumulated experience and the return on experience, which is job-specific. Individuals occasionally get job offers, which consist of a fixed return on experience, drawn from a fixed distribution. An unemployed individual has some probability of getting a job offer in any given period, and an employed worker has some, possibly different, probability of getting an offer. Accepting an offer moves the worker from unemployment to a job or from one job to another. While employed, if the worker may choose to accept an offer from a different job, or he may return to unemployment. In either case, upon separation of the worker-job match, a fixed fraction of the worker's experience is lost. This reflects the job-specific component of a worker's experience. As a consequence, the worker may accept a pay cut when moving to a new job since he will suffer a decline in experience. An unemployed person does not accumulate experience.

The solution to the worker's dynamic problem consists of stopping rules. In the classical search model, the stopping rule is a reservation wage for the unemployed worker, and a reservation wage for the employed worker. In this model, the stopping rule is a reservation return on experience, which is also different for the unemployed and for the employed, and is a function of the level of the individual's experience.

The model implications are the following. Suppose experience is constant in the model. Then, all wage growth is driven by search on-the-job. The higher is the offer probability for the employed individual, the higher is the wage growth and the worker's ex-ante expected utility. Similarly, suppose experience accumulates on the job, but the worker cannot receive job offers while employed. Then, as long as the worker stays employed, he will see his wage increase because of the accumulation of experience. The faster experience accumulates on

[4] Topel and Ward (1992) using a different sample of young male workers from the Longitudinal Employee-Employer Data set, find that 2/3 of wage growth occurs on the job, while the rest is associated with mobility between jobs and movements in and out of unemployment.

the job, the higher is the wage growth and the higher is the ex-ante expected utility. In this sense, experience accumulation and search on-the-job are substitutable forces, each capable of producing an increasing life-cycle profile of wages on its own. The complicating factor is the complementarity between the two forces. Specifically, an increase in the availability of offers while employed increases the worker's reservation return on experience from unemployed. Thus, the duration of the worker's initial unemployment spell decreases and the average return on experience on the first job after unemployment is lower. As a result, the worker starts accumulating experience sooner in his career, which reflects positively on wage growth on the job. Conversely, if experience accumulates faster, the reservation return on experience from unemployment decreases. Thus, at the beginning of his career, the worker may take an "entry-level" job (i.e. one with a low return on experience) in order to accumulate experience. Because of this, the incentive to move up the ladder to higher paying jobs in the future is greater, which implies a higher wage growth between jobs. Because of the complementarity between search on-the-job and experience, the contribution of the two factors cannot be inferred simply by separating wage growth between jobs from wage growth on the job.

Using data on a sample of male highschool workers from the NLSY, I estimate the structural model, and use the estimated parameters to disentangle the contribution of search on-the-job versus experience accumulation, to a worker's career earnings. The accounting measure proposed is based on counterfactual experiments. One measures the drop in welfare (and wage growth) of the worker as a consequence of shutting down a worker's access to search on-the-job. The other measures the drop in welfare (and wage growth) as a result of shutting down experience accumulation.

I find that search on-the-job contributes only about 17% to wage growth and slightly more than 10% to the worker's net present value of earnings. The intuition for the small relative contribution of search on-the-job to a worker net present value of earnings is due to the fact that search on-the-job and search while unemployed are perfect substitutes. When search on-the-job is shut down in the model, the worker responds by becoming more 'selective' in accepting offers from unemployment. When the accumulation of experience mechanism is shut down in the model, the distortion in the worker's decision to accept jobs from unemployment is smaller, and job-to-job mobility increases. Increasing the reservation return on experience from unemployment results in lower wage growth between jobs, which decreases welfare.

The interplay between search and experience is important because it affects the design of labor market policies. In particular, I consider h is the effect of experience accumulation and search on-the job on the optimal unemployment benefit. I close the model by introducing a payroll tax and imposing that the planner's budget is balanced in the long run. In the presence of imperfect credit markets, a positive level of unemployment benefits provides the risk-averse worker with insurance during spells of unemployment. I consider the special case in which no private saving/borrowing by the worker is allowed, in order to isolate the effect of policy on the worker's mobility decisions. I find that the optimal level of insurance and taxes is higher in environments in which worker experience has a high contribution to worker's net present value of earnings. The intuition for this result is that the planner always taxes the most inelastic good. The worker samples job offers from the same distribution while employed as well as while unemployed. Higher payrol taxes and benefits distort the worker decision to leave the unemployment pool and become employed, but the amount of distortion is smaller in an environment in which search on-the-job plays a smaller role.

The paper proceeds as follows. Section 2 outlines the model and the solution concept. Section 3 describes the construction of the NLSY sample and the main summary statistics. Section 4 presents the estimation details and section 5 describes the main findings from the estimated model, the implications on the wage growth and worker welfare, and on the analysis of optimal unemployment insurance.

2 The Model

2.1 The Model Economy

The model builds on the original Burdett (1978) model with search-on-the-job and off the job, in which the worker accumulates experience while working. This experience makes the worker more productive, in a manner explained later. Time is discrete and the horizon is infinite. Let e_t denote the number of periods, including the current one, in which the worker has been employed on a certain job. Let us adopt the convention $e_t = 0$ if the individual is unemployed at time t. Let h_t denote the worker's level of accumulated experience at time t.

Earnings

The worker is risk-averse and maximizes the expected discounted utility of consumption, i.e.

$$\sum_{t=0}^{\infty} \beta^t u(c_t). \tag{1}$$

There is no borrowing or saving by the individual, thus consumption equals earning while employed.[5] At the beginning of her career, the worker starts unemployed, with a level of experience h_0. Each period she is unemployed he enjoys leisure b. If employed, the wage equals the product of the worker's level of accumulated experience h_t, and the job-specific return on experience, p_t i.e.

$$w_t = h_t \cdot p_t. \tag{2}$$

Search

Each period the worker is unemployed, he receives a random offer with probability λ_0. The offer consists of a value of the return on experience p_t, drawn from the distribution $F(p)$ with finite mean and variance and support $p \in (0, \infty)$. The offer is independent accross time and does not depend on the level of accumulated experience h_t. If a random offer arrives, the worker decides to accept it or reject it. If the offer p_t is accepted, then the offered return on experience stays constant as long as the worker is employed at the same job. An employed individual has some probability $\lambda_1$of receiving a job offer in any given period. This job offer is drawn independently from the same distribution F. It does not depend on the level of experience h_t, or on the current return on experience, p_t.

While employed, the worker can decide to quit and become unemployed. He can also be laid off with exogenous probability π^e. I specify a proportional hazard model, in which the lay off probability is a function of the worker's accumulated experience, [6] that is,

$$\log \frac{\pi_t^e}{1 - \pi_t^e} = \gamma_0 + \gamma_1 h_t. \tag{3}$$

Experience

Each period the worker is unemployed, he does not accumulate any new skills, and thus his level of accumulated experience is constant,

$$h_{t+1} = h_t, \text{ if } e_t = 0. \tag{4}$$

The worker accumulates experience at a rate which depends on the current level of experience.

[5] In a more general setting, the worker would operate in a complete or incomplete markets environment, in which she can save and borrow up to a limit, which may be either equal, or lower, respectively, than the expected discounted value of earnings (see Rendon (2004)). Here, I drive the borrowing constraints assumption to the limit mainly because I want to focus on how the level of unemployment compensation changes the individual employment decision and abstract from the savings/borrowing decision.

[6] Anecdotal evidence suggests that when firms are forced to layoff workers, they tend to retain those with the highest tenure with the firm. However, the assumption that π_e depends on e_t instead of h_t would increase the state space without changing the results.

$$h_{t+1} = \nu + \alpha h_t \text{ if } e_{t+1} = e_t + 1. \tag{5}$$

where $\nu > 0,\ 0 \leq \alpha \leq 1$, and $h_0 \leq \frac{\nu}{1-\alpha}$.[7]

When the job-worker relationship dissolves (irrespective of whether the worker changes jobs or become unemployed next period), a constant fraction δ of the worker's accumulated experience is lost. [8], i.e.

$$h_{t+1} = (1-\delta)(\nu + \alpha h_t) \text{ if } e_t > 0 \text{ and } e_{t+1} = 1. \tag{6}$$

Let $U(h)$ denote the expected discounted utility of an individual who is unemployed and has a level of experience h at the start of the period. Let $V(h,p)$ denote the expected discounted utility of an individual who has a level of experience h at the start of period, and is employed in a job offering a return p. Let β denote the discount factor. We can formulate the worker's decision problem as an infinite-horizon dynamic programming problem. Given the deterministic accumulation of experience, and the stationary nature of the shocks (offers and layoffs), the dynamic programming problem is time-invariant. The Bellman equations are the following:

$$U(h) = u(b) + \beta\lambda_0 \mathbb{E}_p \max\left\{U(h), V(h,p)\right\} + \beta(1-\lambda_0)U(h) \tag{7}$$

$$\begin{aligned} V(h,p) = \;& u(hp) + \beta\pi^e(h)U((1-\delta)h') + \beta(1-\pi^e(h))(1-\lambda_1)\max\left\{V(h',p_t), U((1-\delta)h')\right\} \\ & + \beta\left(1-\pi^e(h)\right)\lambda_1 \mathbb{E}_{p'} \max\left\{V(h',p), V((1-\delta)h',p), U((1-\delta)h')\right\} \\ \text{subject to } \;& h' = \nu + \alpha h \\ \text{and } \;& \pi^e(h) = \tfrac{\exp(\gamma_0+\gamma_1 h)}{1+\exp(\gamma_0+\gamma_1 h)} \end{aligned} \tag{8}$$

If the individual is currently unemployed, his expected discounted utility equals the current utility flow $u(b)$, plus the future expected utility. With probability λ_0, an offer p has been received. If the offer is accepted, the future utility is $V(h,p)$. If rejected, the future utility is $U(h)$. If the individual is employed, he receives the current utility $u(hp)$. If he is laid off with probability π^e, he returns to unemployment, and loses a fraction δ of

[7] These assumptions imply that the level of experience increases at a decreasing rate every period the worker stays with the same job. Moreover, at any point in time, the level of experience is bounded from above by $\frac{\nu}{1-\alpha}$.

[8] This partially captures the job-specific component of experience. The job-specific experience by definition depends on the number of periods of tenure with the job, and a more accurate specification would allow δ to be a function of the number of periods of job tenure, which makes the problem less tractable.

experience. If he is not laid off, and he receives an alternative offer p', he has to decide between three alternatives: staying with on the current job, quitting the job and accepting offer p', or quitting the job and becoming unemployed. In the latter two cases, a fraction δ of his experience is lost (last term in equation (8)).

2.2 Decision rules

Lemma 1 *Assume that $u(\cdot)$ is strictly increasing, concave and differentiable and $\lim_{c\to 0} u'(c) = \infty$. Assume that h has a law of motion described by equations (1), (3) and (5). Suppose the distribution F has a finite mean. Then,*

Proposition 2 *(i) there exist unique functions $\{U(h), V(h,p)\}$, $\forall h \in [\underline{h}, \overline{h}]$, $p \in (0,\infty)$ which solve the above dynamic programming problem.*

(ii) Both V and U are strictly increasing in h.

(iii) For any h, the function $V(h,p)$ is weakly increasing in p.

Proof. (in Appendix).

Each period, if unemployed, the worker's decision consists of accepting or rejecting job offers. If employed, the worker decides when to accept a new job offer and when to quit the current job and return to the unemployment pool. The latter is a legitimate event in this model, because experience accumulates differently whether the worker is employed or not. Suppose the offer probability for the unemployed is greater than the offer probability for the employed individual. Then, a worker may accept an "entry-level" job which pays a low return in order to accumulate experience, and then later return to unemployment to search for a better job. As a consequence, all three decision rules are of the reservation wage form.

1. the unemployed worker with experience h will accept any offer higher than the *reservation return on experience from unemployment*, denoted $\widehat{p}_0(h)$, which solves,

$$V(h,\, \widehat{p}_0(h)) = U(h) \tag{9}$$

2. the worker with experience h employed in a job p will accept any offer higher than the *reservation return on experience from employment* denoted $\widehat{p}_1(h,p)$, which solves,

$$V\left((1-\delta)h',\, \widehat{p}_1(h,p)\right) = \max\left\{V(h',p), U((1-\delta)h')\right\} \tag{10}$$

with h' defined as in equation (5).

3. finally, in addition to the exogenous job destruction, the worker may choose to quit the job and become unemployed if the future value from being unemployed exceeds the future value of being employed on the current job, i.e.the worker with experience h employed in a job p will quit to unemployment if,

$$U((1-\delta)h') > V(h', p) \tag{11}$$

Note that the worker makes a decision about her employment status in the next period after the realization of the offer probability takes place. Thus, even if becoming unemployed next period is better than staying with the current job, if he receives a good offer from a different job, his next period's employment status is employed.

2.3 Worker Mobility

This section describes the worker's transition between states (between jobs and between employment and unemployment). The implications of this analysis carry over to the analysis of wage growth, because both wage growth on the job and wage growth between jobs are affected by the worker's endogenous mobility decisions.

2.3.1 Unemployment-employment transition with no search-on-the-job, no quits and no layoffs

This subsection characterizes the worker's decision in the special case of no search on-the-job and no quits or layoffs. In this case, the employment history is characterized by an unemployment spell, followed by an employment spell on one job. In this case, the only decision the worker faces is which jobs to accept or reject while unemployed. Once the worker accepts a job and becomes employed, the growth of his earnings consists of on-the-job wage growth due entirely to the accumulation of experience.

Proposition 3 *Assume that $\lambda_1 = 0$ and that there is no transition from employment to unemployment. Suppose the utility is of the constant relative risk aversion form, $u(c) = \frac{c^{1-\phi}-1}{1-\phi}$. Then the reservation return on experience from unemployment is decreasing in the level of experience, (i.e. $\frac{\partial \widehat{p}_0(h)}{\partial h} \leq 0$).*

Proof. (in Appendix)

The intuition for this result is simple. The higher is the level of experience h, the higher is the opportunity cost of not working, since the per-period utility of unemployment does not depend on h.Two conclusions emerge from this. First, since the level of experience is constant, and the worker does not lose any skills while being idle, the unemployment hazard rate is constant. Second, if the worker starts his job market experience with a higher level of productive experience h_0, he is more likely to find a job sooner, because he is willing to settle for jobs offering a relatively lower return on experience.Thus, the higher the initial level of experience, the lower the spell of unemployment. Suppose there are two different workers which start their career at two different levels of productive experience. Then, the worker with higher initial experience might accept a lower starting wage than the other, but will make up for it by working more periods, such that his ex-ante utility is higher.

Proposition 4 *Suppose the same assumptions from Proposition 1 hold. Then, the reservation return on experience from unemployment is: (i) lower when experience accumulates faster; (ii) weakly higher when the offer probability for the unemployed is higher; (iii) higher if the level of unemployment benefit is higher (i.e.* $\frac{\partial \widehat{p}_0(h)}{\partial \nu} \leq 0$, $\frac{\partial \widehat{p}_0(h)}{\partial \alpha} \leq 0$, $\frac{\partial \widehat{p}_0(h)}{\partial \lambda_0} \geq 0$, $\frac{\partial \widehat{p}_0(h)}{\partial b} \geq 0$*). Also, if there exist two offer distributions* F_1 *and* F_2 *such that* F_1 *first order stochastically dominates* F_2*, then the worker sampling jobs from the first distribution has a higher* $\widehat{p}_0(h)$ *for every* h *than the worker sampling from the second distribution.*

Proof. (in Appendix)

The comparative statics show that when the value of leisure is high, the worker has a longer unemployment spell on average, and a higher initial accepted wage. On the other hand, a higher rate of experience accumulation on the job offsets this effect. This has important implications for the optimal unemployment insurance policy, as discussed in section 6.

2.3.2 Job-to-job transition with no quits or layoffs

In this section I focus on the job-to-job transition. Since the worker never returns to unemployment, without loss of generality I will ignore the employment-unemployment transition. The value of employment becomes

$$\begin{aligned} V(h,p) = {} & u(hp) + \beta\lambda_1 \int_{\widehat{p}_1(h,p)}^{\infty} V((1-\delta)h', p')dF(p') \\ & + \beta\left(1-\lambda_1+\lambda_1 F\left(\widehat{p}_1(h,p)\right)\right)V(h',p) \end{aligned} \tag{12}$$

If all experience is general, and thus transferable from one job to the next, then $\delta = 0$, and the reservation return on experience equals the return offered in the current job, that is $\widehat{p}_1(h,p) = p, \ \forall\, h, p$.Thus, the decision to switch jobs is independent of the level of experience accumulated. However, when $\delta > 0$, switching jobs is costly, as the worker loses a fraction of the accumulated experience. Thus, the new offer comes at a premium to reflect the opportunity cost of experience accumulation, i.e. $\widehat{p}_1(h,p) > p$. The higher is the worker's level of experience, the higher is the amount of experience which is lost in transition, hence the higher is the opportunity cost of moving. This means that the worker with a higher level of experience has a higher reservation return on experience from employment. As experience accumulates, the return premium from the alternative job has to be higher and higher to compensate the worker for the increasing loss of job-specific experience. The following example illustrates the tradeoffs involved with the decision to switch jobs in a 3-period model.

Example 5 *Suppose there are three periods in the model. The worker starts in period* 0 *with a level of experience* h *employed on job* p. *Suppose utility is* $u(c) = \frac{c^{1-\phi}-1}{1-\phi}$. *Suppose there are no quits or layoffs. Then, the reservation return on experience in period* 0 *is increasing in* h.

Proof. (in Appendix)

This result extends to the infinite horizon case. As the next corollary shows, the implication of this result for mobility is that workers switch jobs less often as they grow old, and as their tenure with the job increases.

Corollary 6 *The job-to-job hazard rate, defined as the percentage of employed workers changing jobs is decreasing with tenure on the job, and decreasing over time.*

Proof. The job-to-job hazard rate is $\lambda_1(1 - F(\widehat{p}_1(h,p)))$ and it is decreasing in $\widehat{p}_1(h,p)$. As the tenure with a job increases, experience accumulates and h increases. As time increases, both experience h, and return on experience, p, increase. Hence $\widehat{p}_1(h,p)$ increases, and the hazard rate decreases.

In the standard search model, the job-to-job hazard rate is constant on the job, but each successive job has a lower hazard rate than the previous one. The fact that in this model the job-to-job hazard rate is also a decreasing function of tenure is not surprising. This result is a consequence of the assumption that a fraction of experience is lost upon dissolution of the worker-job match. In Jovanovic (1979a) the probability of separation of the worker-job match decreases with tenure because the worker's learning accumulates with tenure. This match specific learning is a form of specific human capital. In Jovanovic (1979b) the probability of separation decreases with tenure because of firm-specific capital. All these models have in common is the penalty associated with dissolving a match, penalty which increases with worker's tenure with the job.

2.3.3 Worker mobility in the general model

Worker mobility is important because it affects wage growth (both on the job and between jobs) and worker welfare. The previous sections provided some intuition about the forces that affect worker mobility in some special cases of the model. This section illustrates how worker mobility is affected by variation in parameter values through simulations. The baseline parameters used are the estimated parameters from section 5.2. The most relevant results are how worker mobility is affected by variation in the offer probability for the employed, λ_1, and by the slope and intercept of the experience accumulation function, α and ν, respectively. The results are presented in Figures 2.1 through 2.9.

As expected, mobility is very sensitive to variations in the intensity of on-the-job search, but especially in the rate of experience accumulation. An increase in the slope, or the intercept of the experience accumulation function increases the outside option while unemployed, making the worker more 'impatient', thus determining him to exit the unemployment pool sooner. The same effect is caused by an increase in the offer probability for the non-employed. This effect is strong, and it has implications on the job-to-job mobility as well, because the reservation return on experience drops in response to an increase in the rate of accumulation of experience. As a consequence, the worker begins her first employment on a job which pays a lower return on average. This increases the probability of a subsequent job change. This effect is so strong that it offsets the negative effect that experience has on job mobility due to the job-specific component of experience (see previous section). However, as time goes on the worker finds herself in 'better' jobs, and the latter effect becomes more important. This explains the disproportionate effect that an increase in the rate of experience accumulation has on job-to-job mobility earlier in the worker career, as opposed to later.

This finding is important, because it affects wage growth and worker utility, as illustrated in the next section.

2.4 Wage Growth: a 'Horse Race' between Search On-the-Job and Experience Accumulation

In this model, there are two technologies that determine the growth of wages throughout the life-cycle: the accumulation of experience while working and search on-the-job. When experience accumulates at a faster rate on the job, this has a direct effect on wage growth through wage growth on the job. However, there is also an indirect effect. Workers exit the unemployment pool faster on average, because the reservation return on experience from unemployment decreases (see section 2.3.1). That means that on average, workers have a lower return on experience on the first job after the initial unemployment spell. This effect increases the likelihood of job-to-job transition, since the worker draws job offers from the same distribution while employed, as well as unemployed. As a consequence, wage growth between jobs also increases. There is an additional indirect effect that comes from the penalty that a worker incurs when switching jobs, in terms of specific experience forgone. As illustrated in section 2.3.2, this penalty is higher, the higher is the level of accumulated experience. The higher the rate of experience accumulation, the higher the level of accumulated experience at any point in time, resulting in less frequent job changes, and lower wage growth between jobs. This is why the wage growth between jobs cannot be attributed entirely to search on-the-job.

Similarly, an increase in the offer probability for the employed worker contributes to both wage growth between jobs as well as wage growth on the job. First, when the offer probability for the employed, λ_1, increases, job-to-job mobility increases (see previous section). Wage growth between jobs increases because the worker receives more frequent offers while employed. At the same time, since the outside option while unemployed increases, the reservation return on experience for the unemployed drops. As a result, the worker is likely to find a job sooner, and thus starts accumulating experience sooner. This raises the level of experience at any point in time, increasing wage growth on the job.

The 'horse race' between search on-the-job and accumulation of experience is affected by the complementarity between the two as described earlier. One key component of this complementarity is due to the fact that the two forces affect the individual's decision to accept the first job out of unemployment. Unemployment benefits also affect the individual's mobility between unemployment and employment. Therefore, measuring the contribution of search on-the-job relative to that of experience accumulation to a worker's lifetime earnings is important.

2.5 Optimal Unemployment Benefit

This section analyzes the impact of search on-the-job and experience accumulation on the level of optimal unemployment insurance. I assume that the level of unemployment benefits is a flat amount ρ per period, and it is not affected by the duration of the unemployment spell, or the level of worker's experience.[9] To begin with, assume that the policymaker

[9] Papers such as Hopenhayn and Nicolini (1997) or Shavell and Weiss (1979) analyze the optimal unemployment insurance as a function of the duration of the unemployment spell and find that the optimal unemployment insurance should be decreasing in the duration of unemployment. However, as Lentz (2003) emphasizes, these more complex benefit paths are less likely to be politically implementable.

can borrow and lend at the risk-free interest rate $1 + r = \frac{1}{\beta}$, and that the unemployment benefits are financed by a proportional payroll tax. Let τ denote the tax rate. I assume that the policymaker can run budget deficits or surpluses in each period, but it is required to balance the budget over the duration of the worker's career. Let $\Gamma_t(h)$ define the measure of unemployed workers with level of experience h at time t, and $\Psi_t(h,p)$ the measure of workers with level of experience h employed on a job with return p at time t.

The policymaker chooses ρ and τ in order to maximize the representative worker's expected discounted utility subject to the lifetime budget-constraint, i.e.

$$
\begin{aligned}
&\max_{\rho,\, 0\leq\tau\leq 1} u(b+\rho)\sum\left[\beta^t \int \Gamma_t(h)dh\right] + \sum\left[\beta^t \int\int u\left(hp(1-\tau)\right)\Psi_t(h,p)dpdh\right] \\
&\text{s. to } \rho\sum_{t=0}^{\infty}\left[\beta^t \int \Gamma_t(h)dh\right] = \tau\sum_{t=0}^{\infty}\beta^t \int\int hp\Psi_t(h,p)dpdh \\
&\text{and } \Gamma_0 = 1, \Psi_0 = 0, h_0 \text{ given} \\
&U, V \text{ defined as in (6) and (7)}
\end{aligned}
\tag{13}
$$

The main rationale for the provision of unemployment compensation is to provide insurance for the workers, who suffer a loss of income during spells of unemployment. If the workers are risk neutral, then a positive level of unemployment benefits financed by payroll taxes would introduce distortions in the worker's employment decision, resulting in a less than optimal equilibrium. Lemma 2 illustrates this result formally, for the two special case models, the model with experience accumulation but no search on-the job, and the one with search on-the-job but no accumulation of experience.

Lemma 7 *Let $u(c) = c$, and suppose the policy maker chooses a fixed level of unemployment benefits ρ to be paid to the worker for every period the worker is unemployed, and a uniform wage tax rate τ, such that the infinite government budget is balanced. Suppose one of the following two conditions hold:*

(i) $\lambda_1 = 0$ (no on-the-job search).

(ii) $\nu = 0,\ \alpha = 1,\ \delta = 0$ (no accumulation of experience on-the-job).

Then, the optimal policy is $\rho^* = \tau^* = 0$.

Proof. (in Appendix).

When agents are risk-averse, the optimal levels of taxes, and unemployment benefits, respectively, are non-zero, and are affected by the intensity of search on the job as well as the rate of experience accumulation on the job.

In the classical search model without accumulation and experience and without search on-the-job, the risk-averse worker wants to smooth consumption over time. If the value of leisure is low enough and the workers cannot borrow or lend at the risk-free rate, then the optimal amount of unemployment benefits is positive. The 'tighter' the borrowing constraints are, the higher the need for government provided insurance. In that sense, the level of the unemployment benefit calculated in this paper is an upper bound of the optimal level. But more importantly, this paper emphasizes how the planner chooses the level of unemployment insurance in environments where search on-the-job is less or more intense relative to the accumulation of experience.

As shown in section 3.3., an increase in the effectiveness of on-the-job search (offer probability λ_1), as well as an increase in the rate of experience accumulation while working (an increase in α, for example) have the same qualitative effect. They increase the value of the outside option while unemployed, reducing the duration of the unemployment spell. However, they differ in terms of the magnitude of the effect. Both the unemployed and the employed sample from the same distribution, so search while unemployed and search while employed are perfect substitutes. If one eliminates the possibility of on-the-job experience accumulation, the worker cannot compensate for the loss of wages entirely by searching more while unemployed. Thus, the increase in the duration of unemployment is lower than in the case when the search on-the-job activity is shut down.

The purpose of this model is to provide the framework for a quantitative analysis of the relative contribution of search on-the-job versus experience accumulation on one hand, and of the impact of this measurement to unemployment insurance policy. The next section describes the data used in this analysis.

3 Data

3.1 Data sample construction

The data consists of a sample of male highschool graduates from the National Longitudinal Survey of Youth (NLSY). The NLSY data comprises 12,686 individuals who were 14-21 years old when they were first interviewed on January 1, 1979. Since then, they have been interviewed every year until 1994, followed by two other interviews in 1996 and 1998. This is a random, nationally representative sample with an oversampling of blacks and hispanics and military. After controlling for the sex of the respondent, the sample consists of 6,403 males. Out of these, 2,137 workers graduated from highschool between 1979 and 1985 (received a highschool diploma or equivalent) [10]. I restrict the sample to male workers who do not return to school, who are not enrolled in the armed forces and who have a complete employment record for 8 years [11].

The resulting sample consists of 467 male highschool graduates, out of which 68% are white and 23% are black. The sample members are grouped in different cohorts, based on the quarter and year of graduation from highschool (see Table 3.1). There are 27 different cohorts, but by far the largest cohorts in size consist of those graduating in the second quarter (81 percent) and those who graduate before 1983 (77 percent). The average age in the sample is 18 years at the time of joining the sample.

I exploit the panel feature of the data by observing the employment history of each individual in the sample for 8 complete years (32 quarters). The NLSY collects employment data for each week throughout a year. The workhistory file contains weekly data on the employment status of each individual, and if employed in a particular job, the worker reports the job identification number. This number allows one to link jobs over time, constructing employment cycles. A cycle of employment starts with the duration of an unemployment spell and ends with the duration of the last job held before the worker became unemployed again. Thus, each worker's life cycle employment status can be recorded in several cycles, where the $n-$th cycle:

$$s_n = (u_n, e_{n,1}, e_{n,2}, \ldots, e_{n,K})$$

where u_n denotes the unemployment spell in the $n-$th cycle, and $e_{n,1}$ through $e_{n,K}$ corresponds to the employment spell with the first employer through $K-$th employer in the cycle n.

I aggregate data on employment in quarters (each quarter contains 13 weeks). I define the worker to be unemployed in a particular quarter if he declared to be unemployed (or out of the labor force) for at least 7 weeks during that quarter. The weekly data needs to be aggregated because it would be intractible to structurally estimate the model with weekly observations. On the other hand, the tradeoff is that some of the worker's short term mobility data is lost by aggregation. However, evidence suggests that short term job spells that last for less than a quarter are not important for the worker's career decision studied here. If the worker is employed for at least 7 weeks within a quarter, I define him

[10] I further exclude 58 observations on the account of missing or incomplete highschool graduation information

[11] Some individuals have missing information on the employment status and others have missing information on wages or the number of hours per week. There are 7 workers who report extremely high values for wages in some periods and are excluded from the sample. Since the resulting sample consists of only 467 workers, keeping those workers with erroneous wage information would affect some of the conditional moments and it is better if they are left out.

as employed. It is possible for the worker to be employed in more than one job during a quarter. In that case, I select the job at which the worker worked the most number of weeks within the quarter, provided that it is a full time job (meaning that the worker declared he worked at least 30 hours per week on that particular job). A small proportion of workers report holding multiple jobs at the same time. In that case, only one job is selected, based on the above criteria.

The wage rate (per hour) reported by interviewees is the gross nominal wage rate for each particular job. Unfortunately, the data is not able to capture short run fluctuations of the wage rate on the same job. If the worker's salary on a particular job changed throughout the year, the worker is asked to report the average salary on that job. However, since wage contracts between the employer and the employee are not negotiated with a frequency much higher than annual, the within year wage fluctuations on the job are unlikely to be important. I transformed the data into real wages by using the quaterly consumer price index (excluding food and energy).

3.2 Summary statistics

A large share of workers in the sample (roughly half) start their after highschool job market experience already employed. The remaining share, start as unemployed. The latter spend on average 7 quarters as unemployed before they accept their first offer of employment. Figure 3.1 depicts the unemployment hazard rate for this group of workers, defined as the number of unemployed who find a job next quarter divided by the total number still unemployed. The unemployment hazard rate decreases abruptly over time in the sample of initial unemployed, from a 13.8 percent average in the first four years of market experience to less than 5 percent in the next four years. A fraction of 4 percent of the workers initially unemployed in the sample are never employed. Infinite horizon search models with no heterogeneity in initial conditions predict a constant unemployment hazard rate. This is because the offer probability from unemployment as well as the reservation wage are constant over time. This is the case in the present model as well. To reconcile the theory with the data fact, I assume that there exists worker unobserved heterogeneity.[12] Note that as time increases, the number of workers who are unemployed in the first quarter after highschool and who never found a job is decreasing. As a consequence, after the first three years, the unemployment hazard rate moment is very noisy.[13]

[12] See section 5 for details.

[13] The average hazard rate after year 3 is 6% while the standard deviation of observations is 7%.

A typical worker, once employed, moves from job to job, either directly, or by moving back into unemployment and searching while unemployed. Direct job-to-job transitions account on average for 43 percent of all job separations. About 40 percent of all job separations in the NLSY sample are accounted for by quits, and the remaining fraction by layoffs. These are potentially biased in favor of quits, as sometimes workers quit in response to a threat of a future possible layoff. The fundamental distinction between a quit and a layoff, however, is beyond the scope of this paper, therefore I treat both quits and layoffs as job separations and do not attempt to distinguish between the two. The transition from employment to unemployment is decreasing over time, as illustrated in Figure 3.3, from about 8 percent in the first four years of activity to about 4.5 percent in the next four years. The model in this paper also implies a decreasing employment-to-unemployment transition rate over time, because most of the transition is caused by the exogenous separation probability, which is a decreasing function of the accumulated experience for the worker. As time accumulates, so does experience, and the separation probability decreases.

As we move through the eight year period, the direct job-to-job mobility also decreases on average, but the data is very noisy. On average, each quarter over the first four years of job market experience, the worker has a 5.4 percentage chance of switching jobs next period, while only a 4 percent over the next four years (see Figure 3.4). Workers hold on average 3.2 jobs during the first eight years of market experience, out of which about two thirds occur during the first four years. Figure 3.5 illustrates the probability distribution of the number of jobs. Out of 467 workers in the sample, 82 hold only one job throughout the first eight years of job market activity. The model in this paper successfully accounts for the decreasing job-to-job mobility of workers over time (see section 2.3.2). There are two reasons for this. First, over time, worker's experience in the market increases, and he is more likely to have found a good job already, loosely speaking, thus the likelihood of finding a 'better' job decreases. Second, job attachment increases with tenure. This is motivated in part by the existence of job specific experience. The longer the worker is working in a particular job, the higher the opportunity cost of loosing job specific experience once he moves to another job.

Average real wage rates in this subsample are increasing over this period from $5.16 per hour in the first year of labor market participation to about $6.85 in the 8th year (see Table 3.2 and Figure 3.6). On average, the growth rate of wage rates for the cohorts of individuals in this sample are 0.99% per quarter (equivalent to a 4.03 percent annual growth rate). Note that, unlike the life-cycle pattern, the cross section pattern of average wages accross all age groups for male highschool graduates has been flat during the 1980s (see Eckstein and Nagypal (2004)). Hence, the 4 percent annual increase in wage rates is due entirely to the individual life-cycle growth. I select a subsample of workers who start their employment in either of the first two quarters after graduation from highschool and hold a single job throughout the entire 8-year period.[14] Figure 3.6 compares the time series of the mean wage conditional on employment for this sub-sample of workers, with the one for the entire sample. The mean wage increase for the sub-sample is of particular interest because it is entirely due to wage growth on-the-job. The mean wage in the the first year of employment for the single-job holders is roughly the same as for the rest of the sample. After that, the wages grow for the former sub-sample at a faster pace than for the rest. The gap in levels between the two increases initially, only to diminish towards the end of the 8-year interval. Figure 3.7 compares the mean wage series for the single-job holders against the mean wage series for workers who have multiple jobs, but who never quit into unemployment. The wage growth and the wage levels for the latter sub-smaple is higher. The information provided by figures 3.6 and 3.7 jointly, suggests that unemployment spells have a negative impact to wage growth.

There is no strong evidence suggesting that the wage on the first job out of unemployment is a function of the time spent as unemployed, (see Table 3.2.2), which is consistent with the assumption that experience remains constant as long as the worker stays unemployed.

Topel and Ward (1992), using a longitudinal sample from the Longitudinal Employer-Employee Data set, document that approximately two thirds of wage growth during the first 10 years of a young highschool graduate's career occurs on the job. The same observation holds, roughly, for the sample considered here. More than 68% of the overall wage growth happens on the job. About 23% of the overall wage growth is associated with direct job switches, while the remaining fraction is accounted for by transitions from employment into unemployment, and back into employment.

It is possible, however uncommon, in the sample considered, that a job change is associated with a negative wage growth, which is accounted for by the model in this paper. Also, wage growth on the job can be negative. The average wage growth conditional on switching jobs is large, about 30 percent. By contrast, the average wage growth conditional on staying with the same job is small, about 2.7 percent. Moreover, the wage growth between jobs as well as on the job seem to be slightly declining over time (32% in the first four years versus 29% in the last four years for wage growth rate between jobs; 3.4% in the first four years versus 1.9% in the last four years for wage growth rate on-the-job), also a

[14] Half of the single-job holders start their post high school market experience as employed, and most of them are employed for 32 straight quarters.

feature of the data that the present model accounts for.

4 Estimation and Identification

4.1 Identification

Recall that a fraction of workers in the sample start their after highschool job market experience as unemployed. For this subsample, the expected wage on the first job equals $h_0 \int_{\widehat{p}_0}^{\infty} pdF(p)$. Suppose the reservation rules, $\widehat{p}_0$, $\widehat{p}_1$ are known by the econometrician. From the variance of wages on the first job for the sample subsample of workers, one can infer the variance of the distribution of offers, σ_p^2. If the variance of the offer distribution, σ_p, is given, then the initial level of experience h_0 is identified from the expected wage in the first period on the first job for the subsample of initially unemployed. [15]Also, if σ_p is known to the econometrician, the offer probability for unemployment, λ_0, is identified. Then, given h_0, the coefficients of the experience accumulation function, ν and α are identified from the time series of wage growth for single-job holders, because the accumulation of experience is deterministic. Since a fraction δ of experience is lost upon the separation of a worker-job match, and given the assumption that experience accumulates at different rates, the growth in wages immediately following a job change should be higher than in the previous job. The difference of the two identifies δ. Also, the job-to-job transition rate identifies the offer probability for the employed, λ_1. The employment-to-unemployment transition at different times during the eight year career identifies γ_0 and γ_1. When workers return to unemployment after being employed for a number of periods, their level of experience is higher than h_0, and so the reservation return from unemployment changes. Thus, the value of leisure b and the initial worker heterogeneity can be identified from the duration of unemployment spells other than the initial one. Finally, the reservation returns on experience are non-linear functions of all parameters as section 2.3 shows, so the model is identified.

4.2 Estimation algorithm

The parameters of the model are estimated using simulated generalized method of moments (SGMM) estimation developed by McFadden (1989). First, I fix two parameters which are

[15]Here, the assumption that the distribution F is a function of only σ_p^2 is essential for identifying h_0.

not identified separately from the model. In particular I set the discount factor $\beta = 0.98$ to correspond to an annual interest rate of 2%, which is the average return on bonds over the period 1979-1993. Also, since I do not use explicitly any data on the individual's asset position, and I abstract from saving and borrowing, the parameters of the per-period utility function with risk-aversion needs to be taken from outside the model. I assume that a constant relative risk aversion utility, $u(c) = \frac{c^{1-\phi}-1}{1-\phi}$, and set $\phi = 1.3$, as estimated by Rendon (2002). I assume that the distribution of offered returns, F, is lognormal, with mean μ_p and variance σ_p^2.

A fraction $\theta = 0.445$ of workers start their post-highschool market experience already employed. For some of them, especially those from cohorts starting in 1979 and 1980, there are incomplete employment spells because the data collected starts in 1979. Therefore it is impossible to determine their level of experience prior to graduation. For tractability, this paper employs an assumption similar to Wolpin (1987), namely that a fraction θ of workers are employed in the first period in a job drawn randomly from the distribution of returns F, truncated to the left by the reservation return on experience $\widehat{p}_0(h_0)$.

The empirical unemployment hazard rate is decreasing over time (see section 4). However, under the assumption of search on the job and accumulation of experience, the unemployment hazard rate implied by the model is increasing (see section 4.5). To reconcile the two facts, I allow for unobserved heterogeneity of the workers, with respect to the value of leisure. I consider that a measure ζ of the workers have a value of leisure of b_1, while a measure $1 - \zeta$ have a value of leisure of $b_2 > b_1$. [16]

The remaining set of parameters Θ, to be jointly estimated are:

- the parameters determining the speed of experience accumulation: ν, α, δ;
- the parameters affecting the labor market conditions: $\lambda_0, \lambda_1, \gamma_0, \gamma_1, \mu_p$, $\sigma_p, b_1, b_2, \zeta$;
- the initial level of experience: h_0.

Using the data on wages and employment, I construct the following twenty-eight life-cycle moments:

- conditional mobility moments (averaged over two-year intervals): unemployment hazard rate, employment-to-unemployment transition, job-to-job transition

[16] The choice of modelling unobserved heterogeneity in this way was prompted by the data. The model implies a decreasing job-to job mobility with respect to time, thus any source of heterogeneity in parameters affecting the accumulation of experience or the market conditions for the employed, would potentially result in a reversal of the shape of the job-to-job mobility profile making it inconsistent with the data. Another alternative considered was to introduce unobserved heterogeneity with respect to the initial level of experience. However, this would distort the log-normal shape of the distribution of the initial wages.

- wage moments (averaged over one-year intervals): mean wage rate for employed workers, mean wage for single-job holders.

The estimation algorithm proceeds in three steps. First, given a set of parameters, I solve the programming problem. Using the stopping rules derived from the dynamic programming problem (see section 3.1), I generate S random draws of shocks, and for each draw, I simulate data on wages and employment. Using the simulated data I compute the simulated moments corresponding to those above, and then I average over the number of draws. The SGMM estimator is defined as:[17]

$$\widehat{\Theta} = \arg\min_{\Theta} \sum_{k=1}^{28} g_k \left(E_k - \sum_{s=1}^{S} \overline{E}_{ks}(\Theta) \right)^2 \tag{14}$$

where $\overline{E}_k(\Theta)$ is the simulated moment corresponding to the empirical moment E_k, using parameters Θ as input. The minimization uses the 'simulated annealing' algorithm.[18] Given a fixed number of simulations, the SGMM estimator is consistent, and for S large enough, the variance of this estimator converges to the variance of the standard GMM estimator.

5 Results

5.1 Fit of the Model

Table 5.1 compares the data moments with the estimated moments. The model accounts well for the worker mobility from job-to-job and from employment-to-unemployment observed in the data. The empirical unemployment hazard rate shows a steep decline after the first 4 years of market experience. The number of workers who did not find a job for four straight years after highschool is small (less than 10% of the entire sample). Hence, it is likely that the average unemployment hazard rate for the last 4 years is affected by the small sample bias. The model has a decreasing unemployment hazard rate over time, although the decline is not as steep as in the data. As a result, the model overpredicts the number of workers employed in each period (see Figure 5.1).

Recall that the mean wages for single job holders reflects the growth in experience over the worker's career. The model overestimates the mean wage for single job holders in the

[17] The weighting matrix used is diagonal, with weights g_k depending on the number of periods the corresponding moment is averaged over, and the magnitude of the empirical moment. Note that this is not the efficient weighting matrix.

[18] see Goffe, Ferrier and Rodgers (1994).

first four years of employment after highschool by about 3%, and underestimates it after the first 4 years by the same margin. This could be a consequence of the estimated slope of the experience accumulation function being too low (see Table 5.4), or to the estimated starting level of experience being too low, or a combination of the two.[19]

The model does well in accounting for the levels of mean wages for the employed, especially in the first 4 years of the post-high school experience. The mean wage growth for each worker for the entire 8-year period is $1.58 in the model compared with $1.60 in the data. About one third of the increase in wages is associated with the worker changing jobs, which is the same magnitude as in the data. However, 50% of the wage increase in the model is driven by transitions into unemployment and back into employment, while in the data, this represents only 20%. This result is surprising, considering that most drops into unemployment are layoffs, and that the reservation return on experience from unemployment is decreasing in the level of experience. Further investigation is needed to determine the cause of this large wage increase associated with drops into unemployment.

Next, I test the fit of the model, first in terms of the levels of employment and wage rates, and then in terms of conditional mobility. The Mincerian equation, which is a widely used and very robust method which illustrates the correlation between wages and employment. I compare the coefficients of the regression of log wages on the number of periods of past employment and number of periods of past employment squared, using the actual data on wages and employment with the coefficients of the same regression using the simulated data on wages and employment from the model.

The results are shown in Table 5.2. Mean wages are positively correlated with the number of periods the worker has been employed in the past, and the coefficient of the square term is negative. [20] One additional year of experience contributes to about 9% to log wages. The model accounts very well for the relationship between employment and wages in the data. When tenure effects are added to the Mincerian equation, the coefficient of the number of years of experience in the data drops to about 0.05, while in the model, the drop is very modest (0.087). This result is consistent with the earlier observation, which suggests that the wage growth on the job predicted by the model is too low.

With respect to conditional mobility, the model does well in accounting for the declining relationship between mobility (both job-to-job and from employment to unemployment) and the current wage (see Table 5.3). The model does however overpredict the probability of a worker-job match dissolution especially at low levels of wage rates.

[19] As emphasized in section 3, the wage growth slow down towards the end of the 8 year period considered may be due to negative aggregate effects which the model does not account for.

[20] I purposely avoid to define the number of periods the worker has been employed as "experience", in order not to be confused with "productive experience" as defined within the context of this model.

5.2 Parameters

The table below presents the estimated parameters of the model.

Table 5.4 Preliminary estimates

Description (Symbol)	Value
Intercept of the experience accumulation function (ν)	0.581
Slope of the experience accumulation function (α)	0.894
Depreciation rate of experience on job destruction (δ)	0.005
Offer probability for the unemployed (λ_0)	0.473
Offer probability for the employed (λ_1)	0.372
Intercept of exogenous layoff probability function (γ_0)	0.409
Slope of exogenous layoff probability function (γ_1)	-0.753
Standard deviation of the log-normal offer distribution (σ_p)	0.122
Mean of the log-normal distribution (μ_p)	0.017
Initial level of experience (h_0)	4.185
Type one's value of leisure (b_1)	5.552
Type two's value of leisure (b_2)	6.109
Fraction of workers of type one (ζ)	0.607

The parameter estimates have plausible magnitudes and are in line with previous estimates of the parameters of a search model with search on-the-job. Concretely, the offer probability is higher for non-employed than employed, the value of leisure is different for the two types of workers, the coefficients of the offer probability distribution are similar to those found in other studies (Wolpin (1992), Barlevy (2003), etc.). The depreciation rate of experience on job destruction δ, is small, suggesting that tenure effects are small, but not negligible. The evidence on the magnitude of tenure effects in the literature is mixed (see Rubinstein and Weiss (2004) for example), and the particular functional form in which tenure effects are introduced in this model makes a comparison with earlier results even harder. The estimated slope of the experience accumulation function is positive and close to unity, and the intercept is positive.

5.3 Wage decomposition

In this section, I propose a method of disentangling the effects of search on-the-job and experience accumulation, on the ex-post growth of wages, and the ex-ante worker welfare, defined as the expected discounted earnings. Data evidence shows that wage growth associated with job changes accounts for more than one third of overall wage growth, while the wage growth on the job accounts for about 43%. Search on-the-job is the tool through which the worker increases her earnings over time, by sampling better and better jobs. Thus, the argument that search on-the-job contributes more than one third to worker's wage growth over the first eight years of market experience is compelling at a first glance. However, this section argues thatthe wage growth between jobs relative to the overall wage growth statistic provides insufficient information to measure the contribution of search on-the job relative to that of experience accumulation.

The growth rate of wages on the job in period t equals $\nu + \frac{\alpha}{h_t}$, so it is inversely related to the stock of experience at time t. There are two main channels through which search on-the-job affects the rate at which experience accumulates on the job, and consequently the rate at which wages grow on-the-job. First, the higher is the offer probability for the employed, λ_1, the lower is the reservation return from unemployment, $\widehat{p}_0$, so the worker is more likely to start being employed earlier in his career, therefore the growth rate of wages conditional on employment is lower at any point in time. Second, whenever a worker switches jobs, the level of experience goes down because of the specific experience lost in the transition. Thus, more frequent job changes also lead to a lower average level of experience at any point in time, and higher growth rates. Conversely, when experience accumulates faster, it affects the growth rate of wages between jobs. On one hand, the reservation return from unemployment is reduced, leading to higher growth between jobs, and on the other hand, the level of productive experience is higher at any point in time, making job changes less likely because of the penalty involved with job separations. This is why disentangling search on-the-job and experience accumulation as the two main sources of wage growth is not limited to separating wage growth on-the-job from wage growth between jobs.

The setup in this model also allows the analysis of a different question, which is related to the first, but is more relevant to the design of active labor market policies. That is, what is the relative contribution of search on-the-job, and experience accumulation, to a worker's ex-ante expected utility?

To answer these questions, I conduct three counterfactual experiments. In the first one, I shut down the accumulation of experience, and assume that experience is constant throughout the lifecycle (i.e. $\nu = 0,\ \alpha = 1,\ \delta = 0$). In the second one, I shut down the technology of search on-the-job, so that all wage growth comes from accumulation of experience on-the-job. In the third experiment, I abstract from both technologies, reducing the model to the classical search model, in which wages are constant. Let $NPV_{11} = NPV(\widehat{\Theta})$ denote the expected discounted utility in the estimated model. Let $NPV_{01} = NPV(\nu = 0,\ \alpha = 1,\ \delta = 0)$, $NPV_{10} = NPV(\lambda_1 = 0)$ and $NPV_{00} = NPV(\nu = 0,\ \alpha = 1,\ \delta = 0,\ \lambda_1 = 0)$ denote the expected discounted value in each of the three counterfactual experiments, respectively. Define the contribution of search on-the-job relative to experience accumulation to the ex-ante utility as,

$$\xi_{NPV} = \frac{NPV_{01} - NPV_{10}}{NPV_{11} - NPV_{00}} \in [-1, 1]. \tag{15}$$

If ξ_{NPV} is negative and close to -1, the accumulation of experience is the main factor in determing the worker's welfare, because the loss of welfare due to the canceling of experience accumulation is large relative to that due to the elimination of search on-the-job. Similarly, if ξ_{NPV} is positive and close to one, search on-the-job is the main factor contributing to the worker's welfare, and when ξ_{NPV} is close zero, we say that both technologies contribute equally to the worker's welfare. The estimated value of ξ is

$$\xi = \frac{NPV_{01} - NPV_{10}}{NPV_{11} - NPV_{00}} = \frac{0.94146 - 2.52866}{2.93795 - 0.93549} = -0.79,$$

which suggests that for a young male highschool graduate, accumulation of experience contributes to his welfare almost four times more than search on-the-job.

Similarly, define $\overset{\circ}{W}_{11}$, $\overset{\circ}{W}_{01}$, $\overset{\circ}{W}_{10}$, $\overset{\circ}{W}_{00}$as the mean wage growth in the estimated model, the nested model with constant experience, the nested model with no search on-the-job, and the the one with both constant experience and no search on-the-job, respectively. Define the contribution of search on-the-job relative to experience accumulation to wage growth in a similar way and find,

$$\xi_{\overset{\circ}{W}} = \frac{\overset{\circ}{W}_{01} - \overset{\circ}{W}_{10}}{\overset{\circ}{W}_{11} - \overset{\circ}{W}_{00}} = \frac{0.00938 - 1.06382}{1.5815 - 0.0} = -0.667. \tag{16}$$

This means that a fraction of the wage growth between jobs is due to accumulation of experience. The intuition for this result is the following. Search on-the-job and search while unemployed are substitutes. When the former is eliminated from the worker's problem, he makes up for this loss by searching more while unemployed. By contrast, when a worker is deprived of the option of accumulating experience, he cannot fully compensate for it by being more 'patient' while unemployed, because that affects negatively search on-the-job.

There are two caveats to this result. First, as shown in the section 6.1, given the estimated coefficients of the experience accumulation function, wage growth is too high in the model. It is possible that lower coefficient would result in a higher ξ. Second, it is possible that wage growth on the job is a consequence of a variety of other reasons than the accumulation of experience. The future agenda for research prompted by this result is to extend the model to account for counter-offers as in Postel-Vinay and Robin (2002) and to separate between accumulation of experience and counteroffers as two sources of wage growth on the job itself.

6 Policy Experiments

The previous section argued that the disentangling of search on-the-job versus experience accumulation has important implications in the design of optimal labor market policies. To illustrate this idea, in this section, I focus on optimal unemployment insurance. Suppose the planner is solving the problem defined in section 2.5. The worker is risk-averse and operates in an environment in which saving and borrowing are not allowed. The planner chooses a level of the payroll tax rate, and a flat level of unemployment benefits to maximize the worker's expected discounted utility subject to balancing the budget tax revenues and expenditures. Given the complexity of the problem, it would be intractible to compute the planner's lifetime budget constraint, therefore I impose the restriction that the planner has to balance the budget over an eight year period. Figure 6.1 shows a plot of the expected discounted utility as a function of the tax rate. The optimal level of taxes and benefits is zero, because the estimated value of leisure is high enough such that the worker does not need any additional insurance. Some fraction of the workers in the sample receive unemployment benefits at least during a fraction of the time they are unemployed, however, the NLSY data on the level of unemployment benefits received is not rich enough. Also, it is not clear whether the wage rate reported by the worker is net of payroll taxes or not.

In order to focus on non-trivial policies, I modify the environment by decreasing the value of leisure for each of the two types, to 1.0. I construct two hypothetical environments, one with search on-the-job and constant experience (model 1), and one in which experience accumulates, but there is no search on-the-job (model 2), such that without the planner's intervention, the earnings profile generated by each of the two models accounts for the observed earnings profile in the data. First, as the tax rate increases, so does the level of unemployment benefit, because of the monotonicity implied by the budget equation.[21]

The increase in tax rates and benefits increases the worker's reservation return on experience while unemployed, and, consequently, reduces the employment rate in both models (see Figures 6.4 and 6.5). With respect to mean wages, in the model with constant experience, a more aggresive policy would result in higher initial wages for the employed because the reservation return on experience while unemployed is higher. Later, the effect

[21] For fairly large levels of the tax rate not considered here, the relationship becomes negative because the tax revenues exhibit the well-known Laffer curve property.

of policy on mean wages levels off because an employed worker samples jobs from the distribution as an unemployed. Hence, if the initial accepted return is high, the likelihood of receiving an even higher offer while being employed is low (see Figure 6.2). In the model with search on-the-job but constant experience, the entire wage growth is accounted for by search on-the-job. Once the worker accepts a job, the level of the tax rate and benefits does not further affect the accumulation of experience, nor the wage growth on the job. Therefore, higher tax rates and benefits result in higher mean wages at all times for the employed individuals (see Figure 6.3). In the model with no search on-the-job, the level of experience is affected because the worker starts accumulating experience sooner when the tax rates and benefits are low. Nevertheless, as the 8-year horizon approaches, because of the diminishing returns to experience accumulation, the level of experience in a high tax environment starts catching up with the one in the no-tax environment (see Figure 6.6).

Figure 6.7 traces the worker's expected discounted value in each of the two environments as a function of the tax rate. The optimal tax rate in the model with no search on-the-job is 9% and the optimal level of benefits is 2.26. In the model with constant experience, the optimal tax rate is 3% and the optimal level of benefits is 2.07. The intuition for this result can be explained in light of the effect of policy on mobility and wages. In the model with constant experience, when the tax level increases, the level of employment drops. The benefit provided to the unemployed is financed by taxes. Because of the levelling effect observed in Figure 6.2, the increase in tax revenues relative to the model with no search on-the-job is smaller. The planner chooses tax rates and benefits so that to minimize the amount of distortion. That is why the optimal unemployment benefit policy is higher in an environment with no search on-the-job as opposed to one with no experience accumulation.

The optimal taxation theory states that in an economy with a variety of goods with different elasticities of substitution, the planner finds it optimal to tax the most inelastic good. The same reasoning can be extended to this model, because search on-the-job and search while unemployed are perfect substitutes. The planner taxes the more inelastic good, experience, at a higher rate.

7 Conclusion

This paper analyzed the impact of search on-the-job relative to accumulation of experience to workers' increase in earnings and welfare during their early career. Data evidence shows that each job change is associated with large wage gains on average for the worker, and that about one third of the overall wage growth throughout the worker's first eight years of market experience occurs between jobs. In spite of that, according to the measure I propose in this paper, the relative contribution of search on-the-job is very small. The key element to understanding the large effect that work experience has on worker's growth of earnings and welfare is the mobility from unemployment to employment. The worker's reservation return on experience drops sharply in response to an increase in the rate at which experience accumulates on the job, thus decreasing the worker's unemployment spell and the mean accepted wage out of unemployment. Nevertheless, he compensates for the latter by searching on-the-job.

This result has important implications for the design of active labor market policies. In particular, the optimal level of unemployment insurance and implicitly of payroll taxes, in the example considered, is higher in the environment in which experience plays a dominant role.

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8 Appendix

8.1 Proofs

Proof of Lemma 1: First, enlarge the state space to enable a more comprehensive definition of the value functions. Consider the decision problem of a worker (unemployed or employed), who just received an offer of return p'.Denote by $W(e, h, p, p')$ the expected discounted utility of a worker with employment status e (0 if unemployed and 1 if employed), who posesses a level of experience h, working for a job p and who just received an offer p' (by convention, $p = 0$ if the worker is unemployed). Writing the worker's decision problem in this way enables one to characterize the problem in a general way, i.e.

$$\begin{aligned} W(e,h,p,p') \quad = \quad & \max\{u(b) + \beta \int_0^\infty W(0,(\nu+\alpha h)(1-\delta)^e h^{1-e}, 0, p'')dF(p''), \\ & u(hp') + \beta \int_0^\infty W(1,((\nu+\alpha h)(1-\delta))^e h^{1-e}, p', p'')dF(p''), \\ & u(hp)^e u(hp')^{1-e} + \beta \int_0^\infty W(1,(\nu+\alpha h)(1-\delta)^e, p^e p'^{1-e}, p'')dF(p'')\} \end{aligned} \tag{17}$$

This formulation embeds the decision problem of both the unemployed and the employed worker. Then, the following identities hold:

$$U(h) = \int_0^\infty W(0,h,0,p')dF(p') \tag{18}$$

and,

$$V(h,p) = \int_0^\infty W(1,h,p,p')dF(p') \tag{19}$$

Let $X = \{0,1\} \times [\underline{h}, \overline{h}] \times (0,\infty)^2$ denote the state space. I define an operator $T : C(X) \rightarrow C(X)$, where $T(W)$ equals the right hand side of equation (16). This operator maps bounded continuous functions into bounded continuous functions. More over, T is a contraction mapping, satisfying the monotonicity and discounting property. Then, by the Contraction Mapping Theorem, there exists a unique bounded continuous function W^* such that $T(W^*) = W^*$. Equations (17) and (18) imply that there are unique functions U^* and V^* that solve the worker's problem. Moreover, since u is strictly increasing, the operator T maps stictly increasing functions into strictly increasing functions, so U^* and V^* are both strictly increasing in h and weakly increasing in p.

■

Proof of Proposition 1:

Denote by $h^{(n)}$ the level of experience after n periods, given that the current level of experience is h. The net present value of an individual with experience h employed in a job p is:

$$V(h,p) = \frac{(hp)^{1-\phi} - 1}{1-\phi} + \beta V(h', p) \tag{20}$$

Since $h_0 \leq \frac{\nu}{1-\alpha}$, it follows by the continuity of V that $\lim_{n\to\infty} V(h^{(n)}, p) = \frac{(\overline{h}p)^{1-\phi}-1}{(1-\beta)(1-\phi)}$, where $\overline{h} = \frac{\nu}{1-\alpha}$. Then, the first order difference equation has a unique solution

$$V(h,p) = \frac{p^{1-\phi}}{1-\phi} \sum_{i=0}^{\infty} \beta^i \Lambda_i^{1-\phi}(h) - \frac{1}{(1-\phi)(1-\beta)}, \tag{21}$$

where $\Lambda_0 \equiv h$ and $\Lambda_i \equiv \nu \left(\frac{1-\alpha^i}{1-\alpha}\right) + \alpha^i h$ for $i > 0$. Since $\{\Lambda_n\}_{n=0}^{\infty}$ is an increasing and bounded sequence the series is well defined and $V(h,p)$ exists for any h and p.

Given that the worker's experience remains constant while unemployed, the value of unemployment satisfies:

$$U(h) = \frac{b^{1-\phi} - 1}{1-\phi} + \beta\lambda_0 \int_{\widehat{p}_0}^{\infty} V(h,p)dF(p) + \beta(1 - \lambda_0 + \lambda_0 F(\widehat{p}_0(h)))U(h) \tag{22}$$

From the definition of the reservation return from unemployment, one can substitute $U(h)$ by $V(h, \widehat{p}_0(h))$. After substituting for $V(h,p)$ from equation (20) and rearranging,

$$\left[\widehat{p}_0^{1-\phi}\left[1 - \beta(1 - \lambda_0 + \lambda_0 F(\widehat{p}_0))\right] - \beta\lambda_0 \int_{\widehat{p}_0}^{\infty} p^{1-\phi} dF(p)\right] \sum_{i=0}^{\infty} \beta^i \Lambda_i^{1-\phi}(h) = b^{1-\phi} \tag{23}$$

If $\phi > 1$ then the term under the brackets is strictly decreasing in $\widehat{p}_0$ and the series is strictly decreasing in h, which implies that $\widehat{p}_0$ is strictly decreasing in h. Conversely, if $\phi < 1$, the former is strictly increasing in $\widehat{p}_0$ and the latter is strictly increasing in h, which also implies that $\widehat{p}_0$ is strictly decreasing in h. If $\phi \to 1$, the utility converges to the natural logarithm, in which we can derive the analog of equation (22),

$$\sum_{i=0}^{\infty} \beta^i \log(\Lambda_i(h)) + \left\{ \frac{\log \widehat{p}_0}{(1-\beta)^2} \left[1 - \beta(1 - \lambda_0 + \lambda_0 F(\widehat{p}_0))\right] - \frac{\beta\lambda_0}{(1-\beta)^2} \int_{\widehat{p}_0}^{\infty} \log p \, dF(p) \right\} = \frac{\log b}{1-\beta} \tag{24}$$

The first term on the left hand side is strictly increasing in h, while the second term is increasing in $\widehat{p}_0$. It follows that $\widehat{p}_0$ is strictly decreasing in h.

■

Proof of Proposition 2:

Suppose that $\phi > 1$. The left hand side of equation (22) is decresing in $\widehat{p}_0$and increasing in λ_0, which implies $\frac{\partial \widehat{p}_0(h)}{\partial \lambda_0} \geq 0$. Also, the right hand side is decreasing in b, which implies $\frac{\partial \widehat{p}_0(h)}{\partial b} \geq 0$. The left hand side is decreasing in Λ_i, for every i, which in turn is increasing in c and a, so $\frac{\partial \widehat{p}_0(h)}{\partial \nu} \leq 0$ and $\frac{\partial \widehat{p}_0(h)}{\partial \alpha} \leq 0$. One can re-write equation (22) as

$$\left[\widehat{p}_0^{1-\phi}(1-\beta) + \beta\lambda_0 \int_{\widehat{p}_0}^{\infty} \left(\widehat{p}_0^{1-\phi} - p^{1-\phi}\right) dF(p)\right] \sum_{i=0}^{\infty} \beta^i \Lambda_i^{1-\phi}(h_t) = b^{1-\phi} \tag{25}$$

Consider two economies that are identical in all aspects but returns from experience are drawn from the distribution F_1in the first one, and F_2 in the second, respectively, such that F_1 first order stochastically dominates F_2. Since $\widehat{p}_0^{1-\phi} - p^{1-\phi}$ is an increasing and concave function with respect to p, it follows that $\int_{\widehat{p}_0}^{\infty} \left(\widehat{p}_0^{1-\phi} - p^{1-\phi}\right) dF_1(p) \geq \int_{\widehat{p}_0}^{\infty} \left(\widehat{p}_0^{1-\phi} - p^{1-\phi}\right) dF_2(p)$. Then workers sampling from the first distribution will have a higher reservation return on experience.

The same proof applies for the other two remaining cases, $\phi < 1$ and $\phi = 1$.

■

Example (Proof):

As in the previous proof, assume, without loss of generality, that $\phi < 1$. Suppose that at time $t = 0$ the worker has experience level h and works in a job p. At the end of the period the worker decides either to stay on the same job, or switch to job p'. Later, at time $t = 1$, if in job p the worker may choose to switch to job p'', and if in job p', she may choose to switch to job p''', respectively. The graph illustrates at each decision node, the level of experience and the corresponding return on experience specific to each job.

Notice that the value of the reservation return in the last period does not depend on h. Hence, the returns on jobs p'' and p''' must satisfy: $p''(1-\delta) = p$ and $p'''(1-\delta) = p'$. Computing backwards, the net present values in the two nodes at time 1 are:

$$V(h_1, p) = \frac{(ph_1)^{1-\phi} - 1}{1-\phi} + \beta\frac{h_2^{1-\phi}}{1-\phi}\Omega(p) - \frac{\beta}{1-\phi}, \tag{26}$$

and,

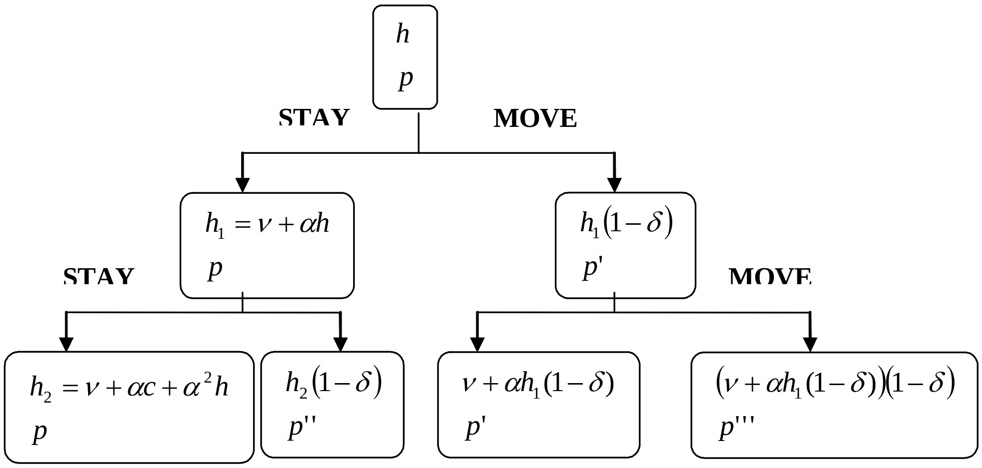


Figure 1:

$$V(h_1(1-\delta),p') = \frac{(p'h_1(1-\delta))^{1-\phi}-1}{1-\phi} + \beta\frac{(\nu+\alpha h_1(1-\delta))^{1-\phi}}{1-\phi}\Omega(p') - \frac{\beta}{1-\phi}, \tag{27}$$

where I define $\Omega(x) \equiv \lambda(1-\delta)^{1-\phi}\int_{\frac{x}{1-\delta}}^{\infty}\widetilde{p}^{1-\phi}dF(\widetilde{p})+\left(1-\lambda+\lambda F\left(\frac{x}{1-\delta}\right)\right)x^{1-\phi}$. The worker is indifferent between working on job p or switching to job p' in period 1 if $V(h_1,p) = V(h_1(1-\delta),p')$, which implies

$$\left[(p'(1-\delta))^{1-\phi} - p^{1-\phi}\right]h_1^{1-\phi} = \beta\left[h_2^{1-\phi}\Omega(p) - (\nu+\alpha h_1(1-\delta))^{1-\phi}\Omega(p')\right] \tag{28}$$

After differentiating equation (27) with respect to h and rearranging, one gets:

$$\begin{aligned}&\tfrac{dp'}{dh}\left\{(1-\delta)^{1-\phi}h_1^{1-\phi}(1-\phi)p'^{-\phi} + \beta(\nu+(1-\delta)\alpha h_1)\Omega'(p')\right\} = \\ &= \beta(1-\phi)\alpha\left[h_2^{-\phi}\Omega(p) - (\nu+(1-\delta)\alpha h_1)^{-\phi}(1-\delta)\Omega(p') + \left((p'(1-\delta))^{1-\phi} - p^{1-\phi}\right)h_1^{1-\phi}\right]\end{aligned} \tag{29}$$

The term on the left hand side is positive because Ω is an increasing function. On the right hand side of the equation, substitute the last term from equation (27). Then, the sign of the derivative depends on the sign of

$$\begin{aligned}&\tfrac{(\nu+\alpha\nu+\nu^2h)}{(\nu+\alpha\nu+\alpha^2h-\alpha\nu\delta-\alpha^2\delta h)}(\nu+\alpha h_1(1-\delta))^{1-\phi}\Omega(p') - h_2^{1-\phi}\Omega(p) \geq \\ &\geq (\nu+\alpha h_1(1-\delta))^{1-\phi}\Omega(p') - h_2^{1-\phi}\Omega(p)\end{aligned} \tag{30}$$

which implies that if $p \geq p'(1-\delta)$, then the derivative is positive, and the reservation return on experience in period one is increasing in h. It remains to show that $p \geq p'(1-\delta)$.

Suppose not. Then, in period one, the worker rejects the offer $\overline{p} = \frac{p}{1-\delta}$. Since p and $\overline{p}$ offer the same current returns, then it must be the case that the future expected utility from rejecting the offer exceeds the future expected utility from accepting it. This means that

$$h_2^{1-\phi}\Omega(p) > (\nu + \alpha h_1(1-\delta))^{1-\phi}\Omega\left(\frac{p}{1-\delta}\right) \geq \frac{(\nu + \alpha h_1(1-\delta))^{1-\phi}}{(1-\delta)^{1-\phi}}\Omega(p), \tag{31}$$

which is a contradiction, because $\Omega(p)$ is positive, and $h_2(1-\delta) < \nu + \alpha h_1(1-\delta)$.[22]
■

Proof of Lemma 2:

If agents are risk neutral, one can substitute ρ from the planner's budget equation into the objective function, and the planner's problem becomes:

$$\begin{array}{l} \max\limits_{\rho, 0 \leq \tau \leq 1} b \sum\limits_{t=0}^{\infty} \beta^t \int \Gamma_t(h)dh + \sum\limits_{t=0}^{\infty} \beta^t \int\int hp\Psi_t(h,p)dpdh \\ \text{s.to } \rho \sum\limits_{t=0}^{\infty} \left[\beta^t \int \Gamma_t(h)dh\right] = \tau \sum\limits_{t=0}^{\infty} \beta^t \int\int hp\Psi_t(h,p)dpdh, \\ \text{and } \Gamma_0 = 1, \Psi_0 = 0, h_0 \text{ given,} \\ U, V \text{ defined as in (6) and (7).} \end{array} \tag{32}$$

(i) Given the stopping rules, the problem is equivalent to one in which the social planner chooses ρ, τ and $\widehat{p}_0(h_0)$ simultaneously to maximize the objective function, subject to the planner's lifetime budget constraint and the equation for the reservation return on experience from unemployment, which, if there is no search on-the-job, is

$$\frac{b+\rho}{1-\tau} = \left\{ [1 - \beta(1 - \lambda_0 + \lambda_0 F(\widehat{p}_0))]\, \widehat{p}_0 - \beta\lambda_0 \int_{\widehat{p}_0}^{\infty} pdF(p) \right\} \sum_{t=0}^{\infty} \beta^t \Lambda_t(h_0). \tag{33}$$

The summation resembles a power series and can be calculated explicitly,

$$\sum_{t=0}^{\infty} \beta^t \Lambda_t(h_0) = \frac{\beta\nu + (1-\beta)h_0}{(1-\beta)(1-\beta\alpha)} \tag{34}$$

Denote $\vartheta \equiv 1 - \beta(1 - \lambda_0 + \lambda_0 F(\widehat{p}_0)$. Without search on the job, it is possible to obtain closed form expressions for the measure of employed or unemployed workers, as follows:

$$\Gamma_t(h) = \begin{cases} \vartheta^t & \text{if } h = h_0, \\ 0 & \text{otherwise.} \end{cases} \tag{35}$$

and

[22] The second inequality follows from the fact that $\Omega(ax) \geq a^{1-\phi}\Omega(x)$, holds for every x and every $a \geq 1$.

$$\Psi_t(h,p) = \begin{cases} \lambda_0 \vartheta^i f(p) & \text{if } h = \Lambda_{t-1-i}(h_0),\ p \geq \widehat{p}_0,\ i = \{0,\ldots,t-1\}, \\ 0 & \text{otherwise} \end{cases} \tag{36}$$

Equations (34) and (35), together with the initial conditions, imply that,

$$\sum_{t=0}^{\infty} \beta^t \int \Gamma_t(h) dh = \frac{1}{1-\beta\vartheta}, \tag{37}$$

and,

$$\sum_{t=0}^{\infty} \beta^t \int\int hp\Psi_t(h,p) dp dh = \frac{[\beta\nu + (1-\beta)h_0]}{(1-\beta)(1-\beta\alpha)(1-\beta\vartheta)} \beta\lambda_0 \int_{\widehat{p}_0}^{\infty} p dF(p). \tag{38}$$

Use equations (36) and (37) to substitute for the infinite sums in the objective function and the budget constraint and the planner's problem becomes:

$$\max_{\widehat{p}_0} \frac{b(1-\beta)(1-\beta\alpha) + \beta\lambda_0[(1-\beta)h_0 + \beta\nu] E(p|p \geq \widehat{p}_0)}{1-\beta(1-\lambda_0+\lambda_0 F(\widehat{p}_0))} \tag{39}$$

This is an unconstrained optimization problem, and the derivative of the objective function with respect to $\widehat{p}_0$ is equal to

$$\frac{\beta\lambda_0 f(\widehat{p}_0)(1-\beta)(1-\beta\alpha)}{[1-\beta(1-\lambda_0+\lambda_0 F(\widehat{p}_0))]^2} \left\{ b + \frac{[\beta\nu + (1-\beta)h_0]}{(1-\beta)(1-\beta\alpha)} [\beta\lambda_0 E(p|p \geq \widehat{p}_0) - \widehat{p}_0\vartheta] \right\} \tag{40}$$

Using (37), one can write the budget constraint as:

$$\rho = \tau\beta\lambda_0 \frac{[\beta\nu + (1-\beta)h_0]}{(1-\beta)(1-\beta\alpha)} E(p|p \geq \widehat{p}_0), \tag{41}$$

Finally, substituting (40) and the reservation return equation (32) into (39), one gets

$$-\frac{\tau\beta\lambda_0 f(\widehat{p}_0)\widehat{p}_0 [\beta\nu + (1-\beta)h_0]}{[1-\beta(1-\lambda_0+\lambda_0 F(\widehat{p}_0))]} \leq 0, \tag{42}$$

and the objective function is decreasing in the reservation return from unemployment, $\widehat{p}_0$. Since, $\widehat{p}_0$ is increasing in τ, the planner will choose not to distort the worker's mobility decision, i.e. $\rho^* = \tau^* = 0$.[23]

(ii) Assume without loss of generality that $\lambda_0 = \lambda_1 = \lambda$. Suppose there is no accumulation of experience, such that $h_t = h_0,\ \forall t$. Normalize the amount of initial experience to

[23] Note that if the planner is not constrained to positive employment benefits policies, the optimal policy would involve negative tax rates and negative unemployment benefits such that $\widehat{p}_0(h_0) = 0$.

one, and redefine the measures of employed and unemployed as $\Psi_t(p)$ and Γ. Then, given that there is no return from employment to unemployment,

$$\mu_t = (1 - \lambda + \lambda F(\widehat{p}_0))^t \equiv \vartheta^t. \tag{43}$$

The measure of employed workers follows the dynamic law of motion,

$$\Psi_{t+1}(p) = \vartheta^t \lambda f(p) + \Psi_t(p)(1 - \lambda + \lambda F(p)) + \lambda f(p) \int_{\widehat{p}_0}^{p} \Psi_t(x)dx, \tag{44}$$

where $\Psi_1(p) = \lambda f(p)$, for $p \geq \widehat{p}_0$.This difference equation has a closed form solution,

$$\Psi_t(p) = t\lambda f(p) \left(1 - \lambda + \lambda F(p)\right)^{t-1}, \text{ for } p \geq \widehat{p}_0. \tag{45}$$

Using (44) and simpliflying, the objective function as a function of $\widehat{p}_0$ is:

$$\max_{\widehat{p}_0} \frac{b}{1 - \beta(1 - \lambda + \lambda F(\widehat{p}_0)} + \sum_{t=1}^{\infty} \beta^t t\lambda \int_{\widehat{p}_0}^{\infty} p f(p)(1 - \lambda + \lambda F(p))^{t-1} dp \tag{46}$$

Taking first order conditions with respect to $\widehat{p}_0$ and re-arranging, obtain,

$$\frac{\beta\lambda f(\widehat{p}_0)}{\left[1 - \beta(1 - \lambda + \lambda F(\widehat{p}_0)\right]^2}(b - \widehat{p}_0) \tag{47}$$

The Bellman equations and the reservation return equations imply that $b = \widehat{p}_0(1-\tau) - \rho \leq \widehat{p}_0$, hence the objective function is weakly decreasing in $\widehat{p}_0$. Thus, the planner will choose the level of the tax rate for which $\widehat{p}_0$ is the smallest, which is $\rho^* = \tau^* = 0$.

■

8.2 Moments definition

- the yearly average unemployment hazard rate, defined as the number of individuals who accept a job in period $t+1$, conditional on being unemployed in all periods from 0 to t.

$$E_j = \frac{1}{8} \sum_{t=8j-7}^{8j} \frac{\sum_{i=1}^{N} I_{\{A_{t+1} \cap (C_1 \cap \ldots \cap C_t\}}}{\sum_{i=1}^{N} I_{\{C_1 \cap \ldots \cap C_t\}}}, j = 1, \ldots, 4 \tag{48}$$

where I is the indicator function, $A_t = \{i = 1, \ldots, N \mid e_t^i = 1\}$, $B_t = \{i = 1, \ldots, N \mid e_t^i > 1\}$, $C_t = \{i = 1, \ldots, N \mid e_t^i = 0\}$, and e_t^i denotes the the number of periods of tenure on a job for the i individual, at the end of the period t (0 if unemployed, by convention).

- the job-to-job transition rate defined as the number of workers who change jobs between t and $t+1$, conditional on being employed at time t, i.e.

$$E_{j+4} = \frac{1}{8} \sum_{t=8j-7}^{8j} \frac{\sum_{i=1}^{N} I_{\{A_{t+1} \cap (A_t \cup B_t)\}}}{\sum_{i=1}^{N} I_{\{A_t \cup B_t\}}}, \quad j = 1, \ldots, 4 \tag{49}$$

- the employment-to-unemployment transition rate defined as the number of workers who become unemployed at time $t+1$, conditional on being employed at time t, i.e.

$$E_{j+8} = \frac{1}{8} \sum_{t=8j-7}^{8j} \frac{\sum_{i=1}^{N} I_{\{C_{t+1} \cap (A_t \cup B_t)\}}}{\sum_{i=1}^{N} I_{\{A_t \cup B_t\}}}, \quad j = 1, \ldots, 4 \tag{50}$$

- the mean wage during the first period of employment, second, and so on, for single-job holders (averaged over one-year intervals), i.e.

$$E_{j+12} = \frac{1}{4} \sum_{t=4j-3}^{4j} \frac{\sum_{i=1}^{N} w_{t+k}^i \, I_{\{C_1 \cap \ldots \cap C_k \cap A_{k+1} \cap B_{k+2} \cap \ldots\}}}{\sum_{i=1}^{N} I_{\{C_1 \cap \ldots \cap C_k \cap A_{k+1} \cap B_{k+2} \cap \ldots\}}}, \quad j = 1, \ldots, 8 \tag{51}$$

where w_t^i is the wage rate of worker i in period t.

- the mean wage for the employed workers at time t (averaged over one-year intervals), i.e.

$$E_{j+20} = \frac{1}{4} \sum_{t=4j-3}^{4j} \frac{\sum_{i=1}^{N} w_t^i \cdot I_{\{B_t \cup A_t\}}}{\sum_{i=1}^{N} I_{\{B_t \cup A_t\}}}, \quad j = 1, \ldots, 8 \tag{52}$$

8.3 Tables and Figures

Figures 2.1 through 2.9 depict the variation in mobility with respect to changes in the slope and intercept of the experience accumulation function (ν and α, respectively) and the offer probability for the employed, λ_1. The benchmark parameters used are the model estimates from Table 5.2.

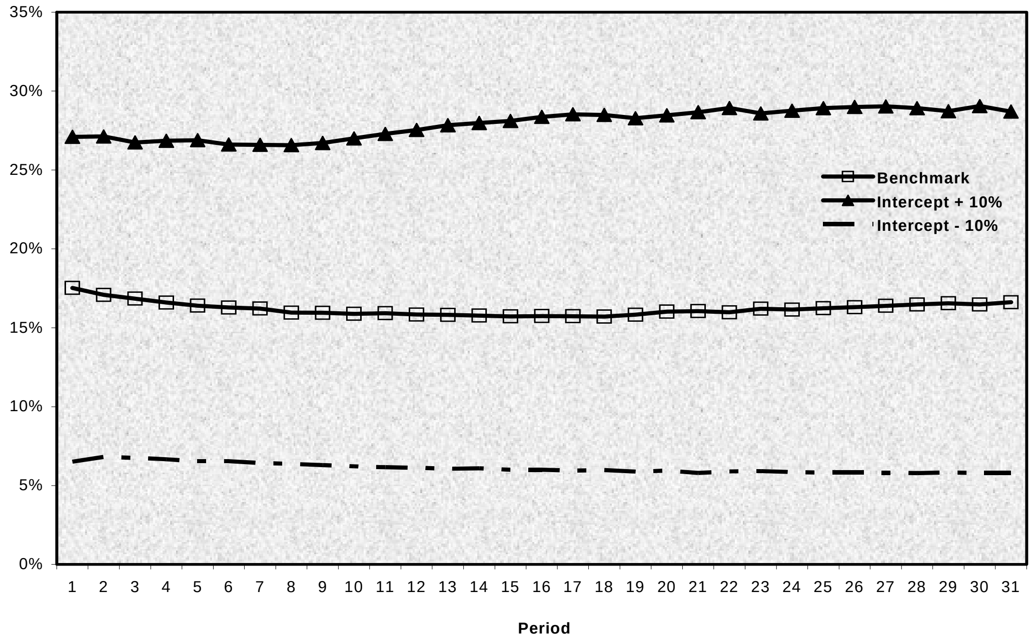


Figure 2.1 Unemployment-to-Employment transition rate (varying ν)

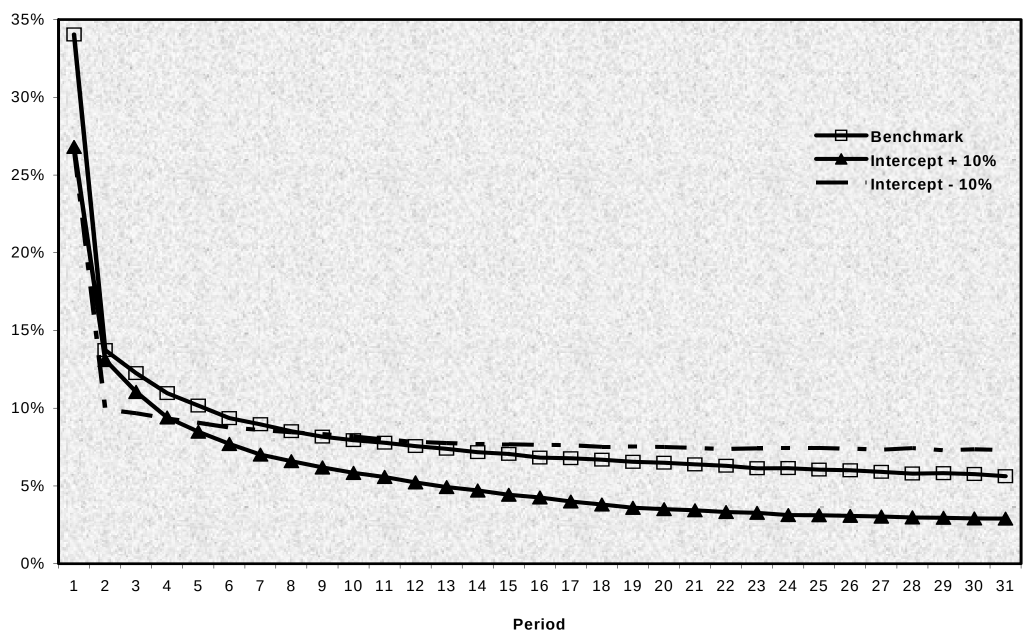


Figure 2.2 Employment-to-Unemployment transition (varying ν)

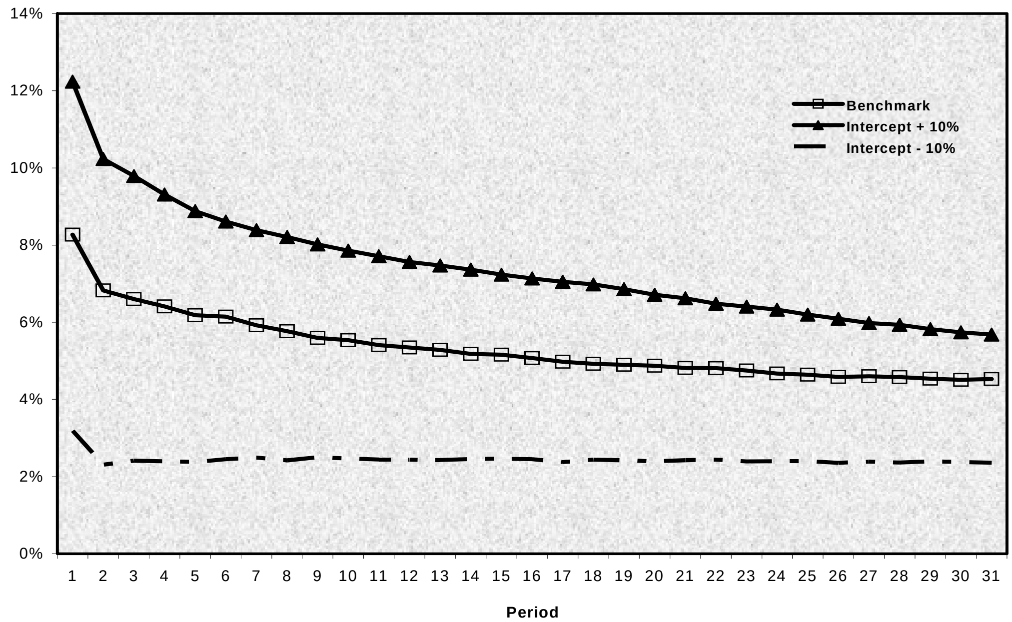


Figure 2.3 Job-to-Job transition rate (varying ν)

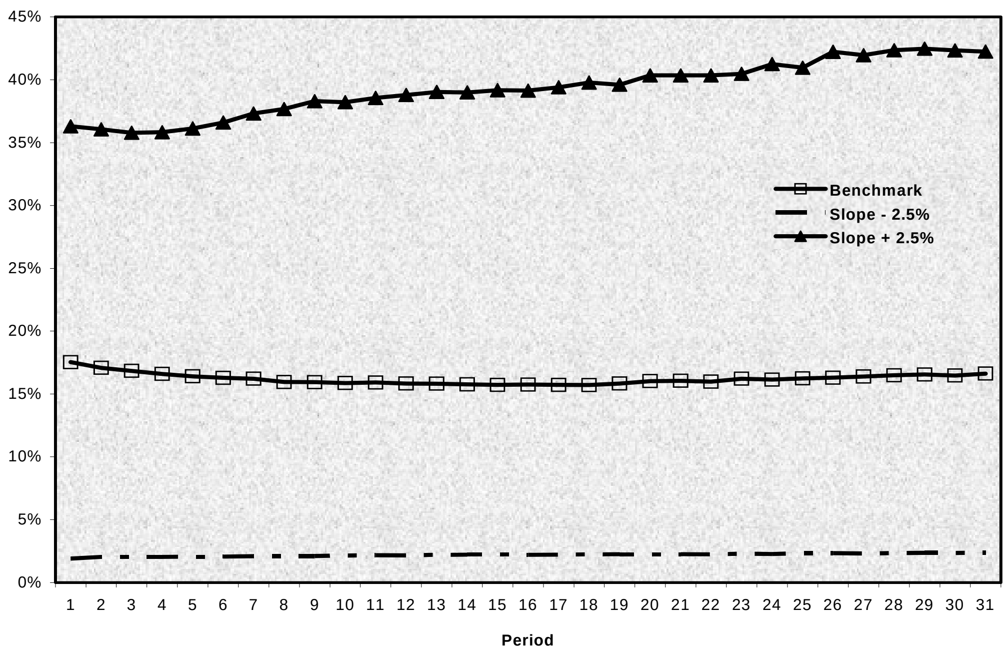


Figure 2.4 Unemployment-to-Employment (varying α)

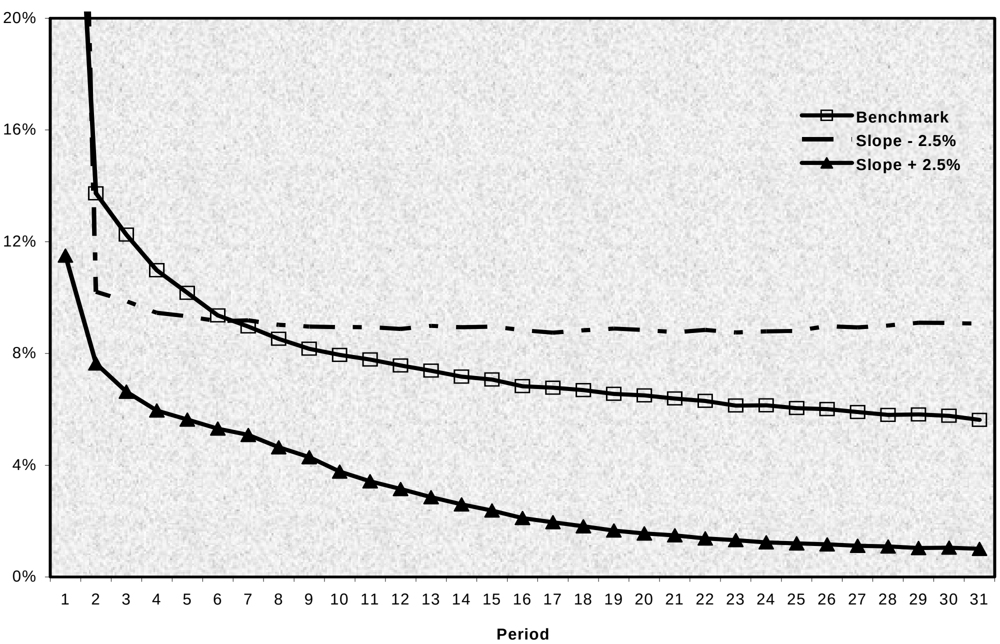


Figure 2.5 Employment-to-Unemployment transition rate (varying α)

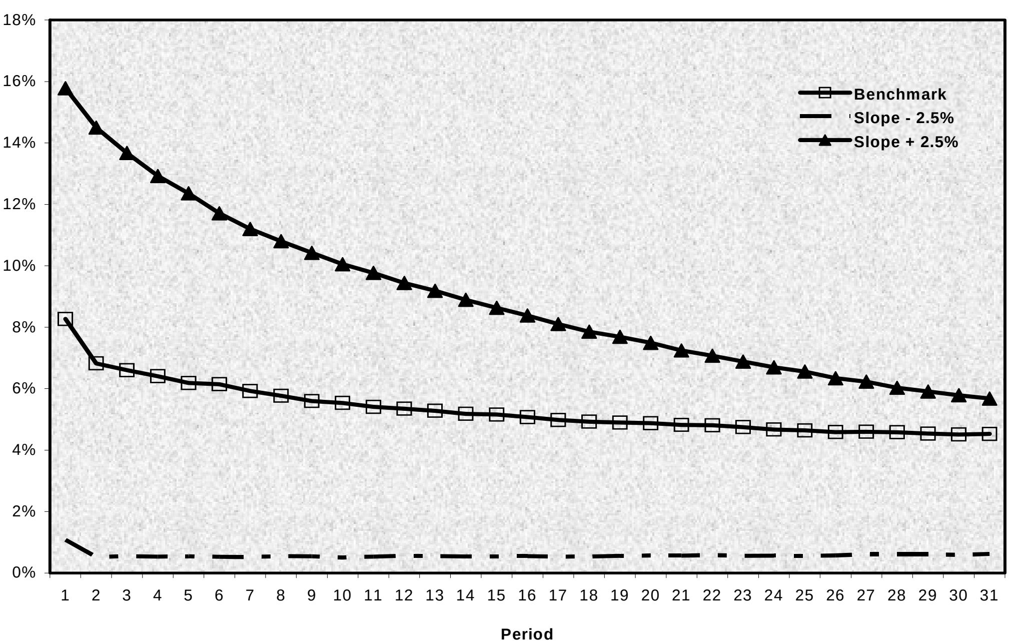


Figure 2.6 Job-to-Job transition rate (varying α)

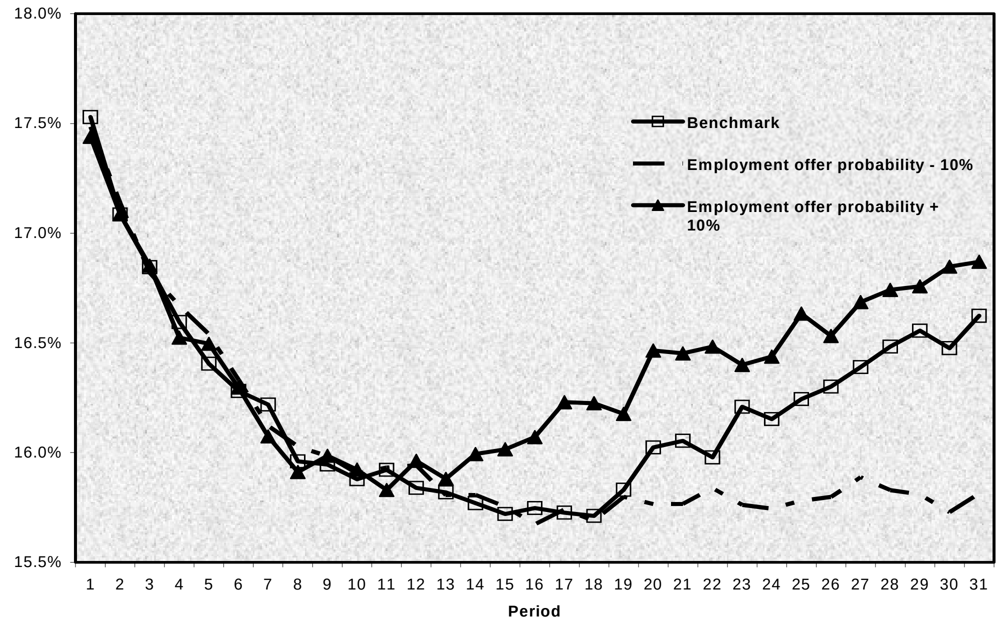


Figure 2.7 Unemployment-to-Employment transition rate (varying λ_1)

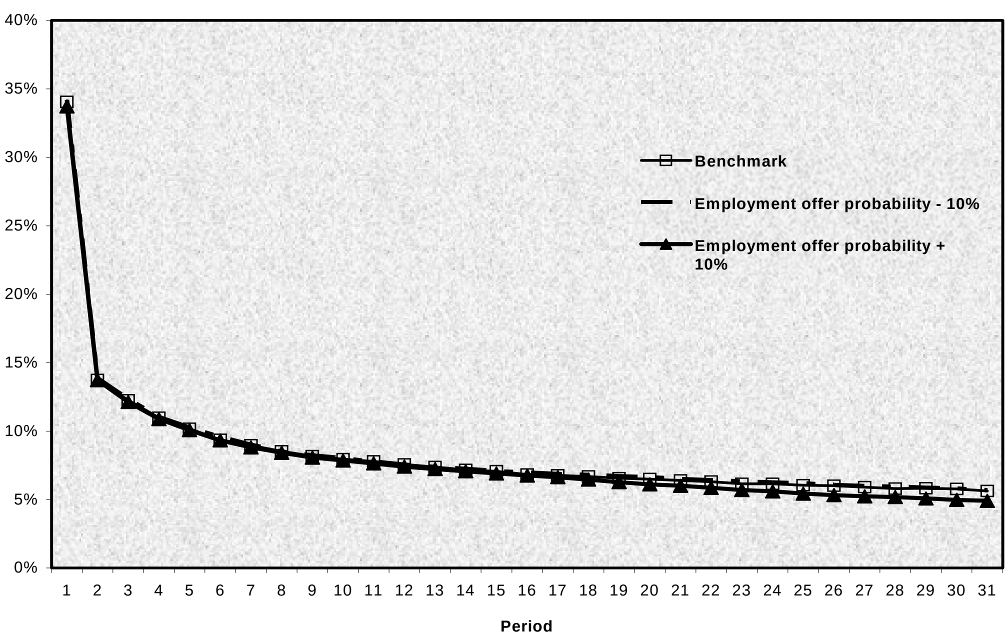


Figure 2.8 Employment-to-Unemployment transition rate (varying λ_1)

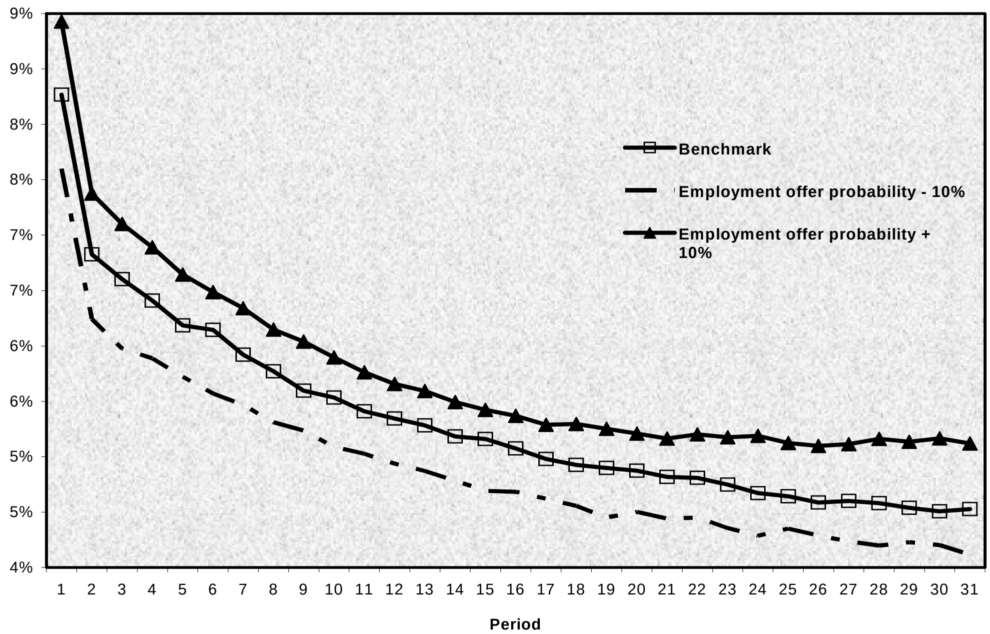
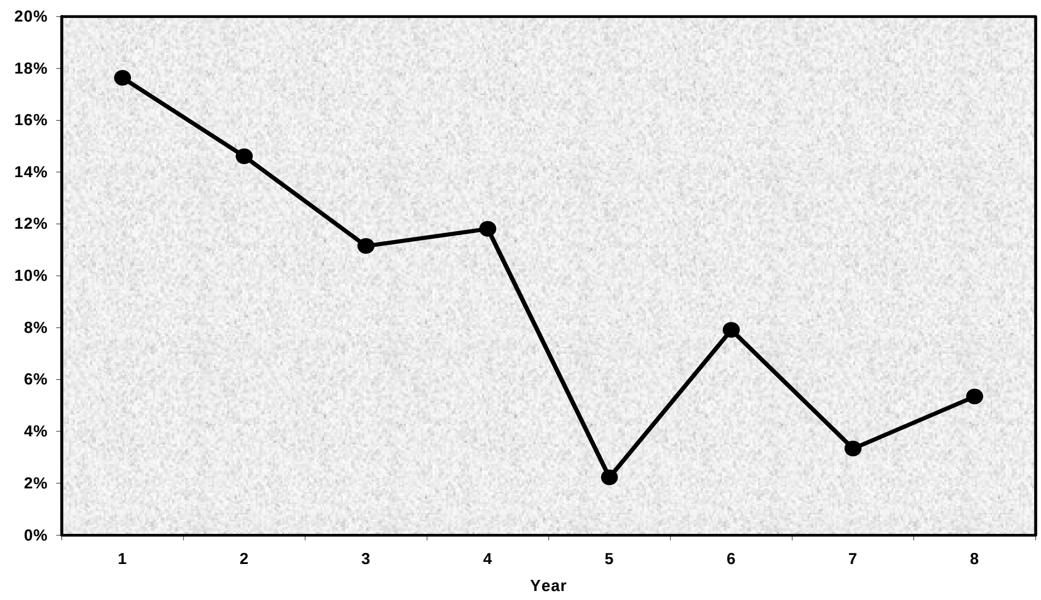


Figure 2.9 Job-to-Job transition rate (varying λ_1)

Table 3.1 The number of workers in each cohort by year and quarter in which they start their post-highschool job market experience

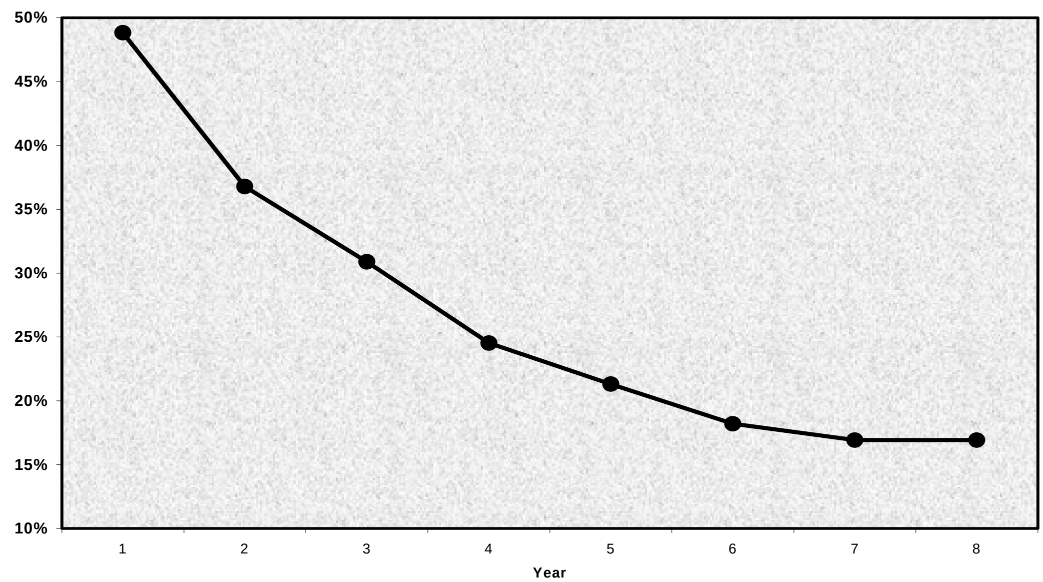
	Quarter 1	Quarter 2	Quarter 3	Quarter 4
1979	0	5	9	1
1980	0	3	95	6
1981	6	4	96	10
1982	4	8	105	9
1983	5	6	51	6
1984	3	5	15	4
1985	1	2	3	3
1986	2	0	0	0

Figure 3.1 Unemployment Hazard Rate



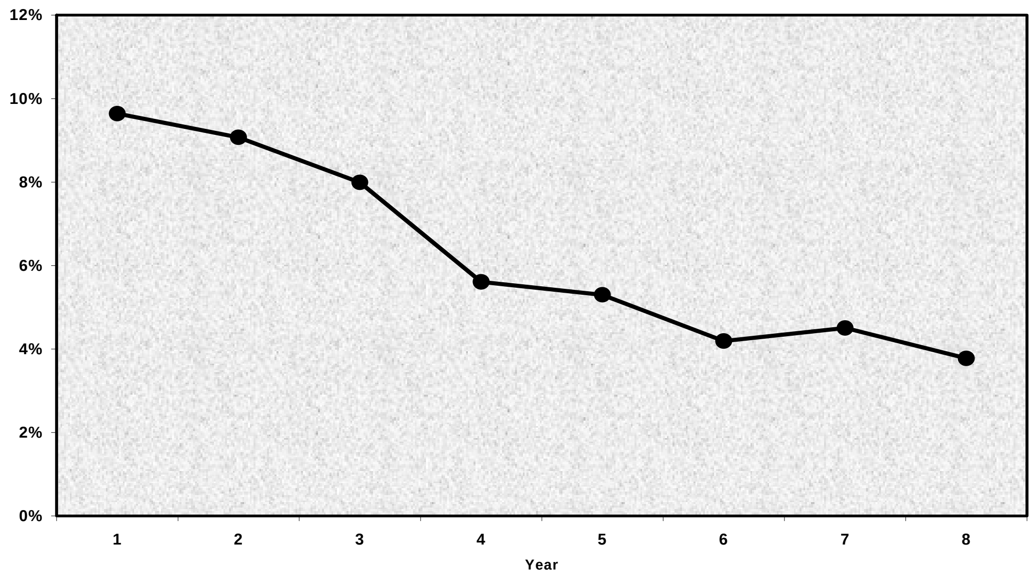
Annual averages of Kaplan-Meyer estimates based on the NLSY sample of 467 workers.

Figure 3.2 Percentage of workers not employed



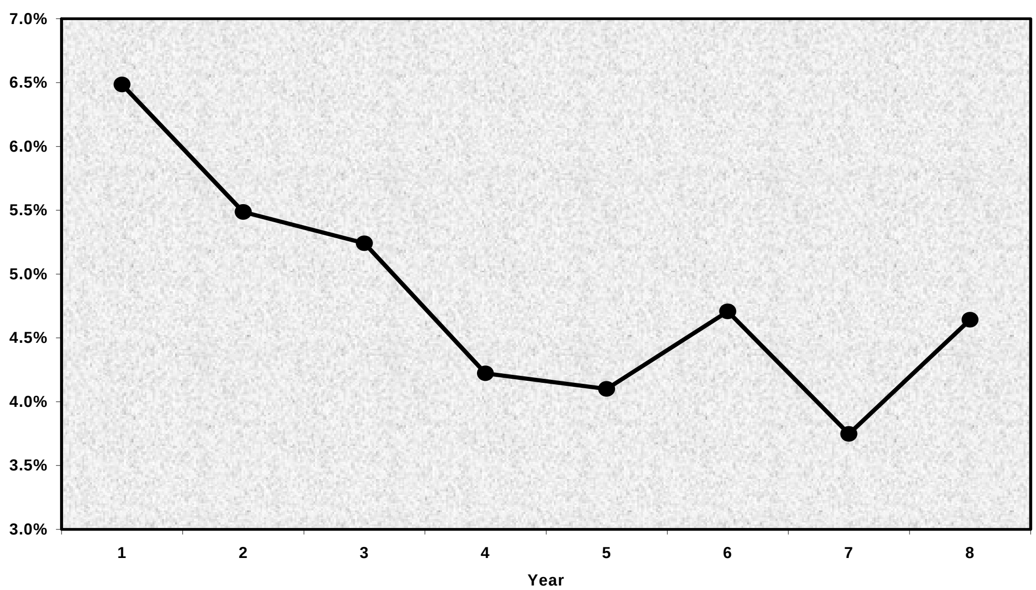
Based on the NLSY sample. Initially, half the workers in the sample start as employed in the first quarter after graduation from high school. Yearly averages.

Figure 3.3 Employment-to-Unemployment Transition Rate



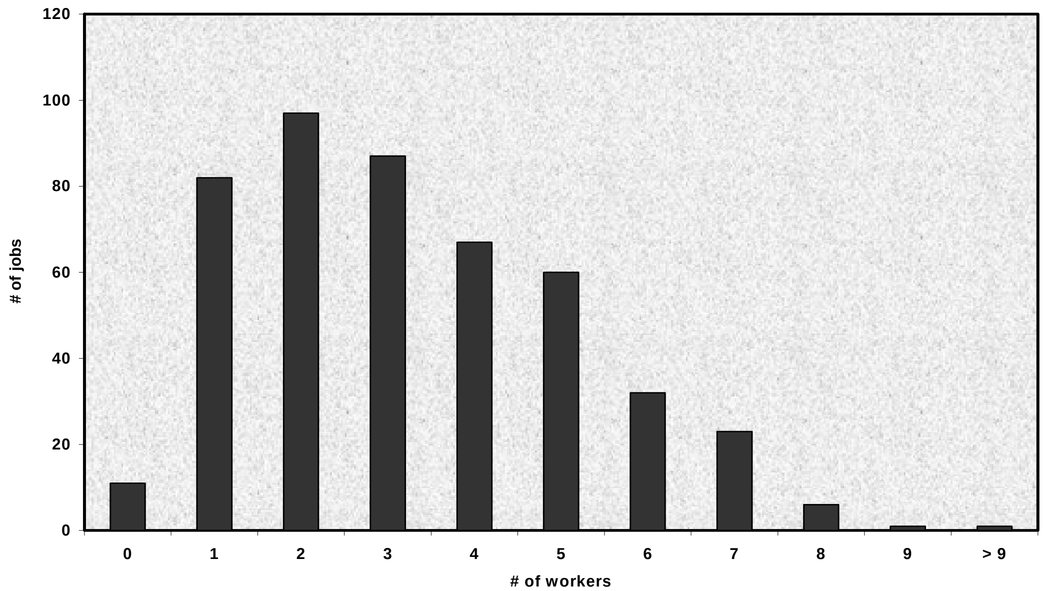
Source: NLSY. Quaterly moments averaged over one-year periods. Employment-to-unemployment transition rate is defined as the number of workers who quit or are layed off and return to unemployment divided by the total number employed.

Figure 3.4 Job-to-Job Transition Rate



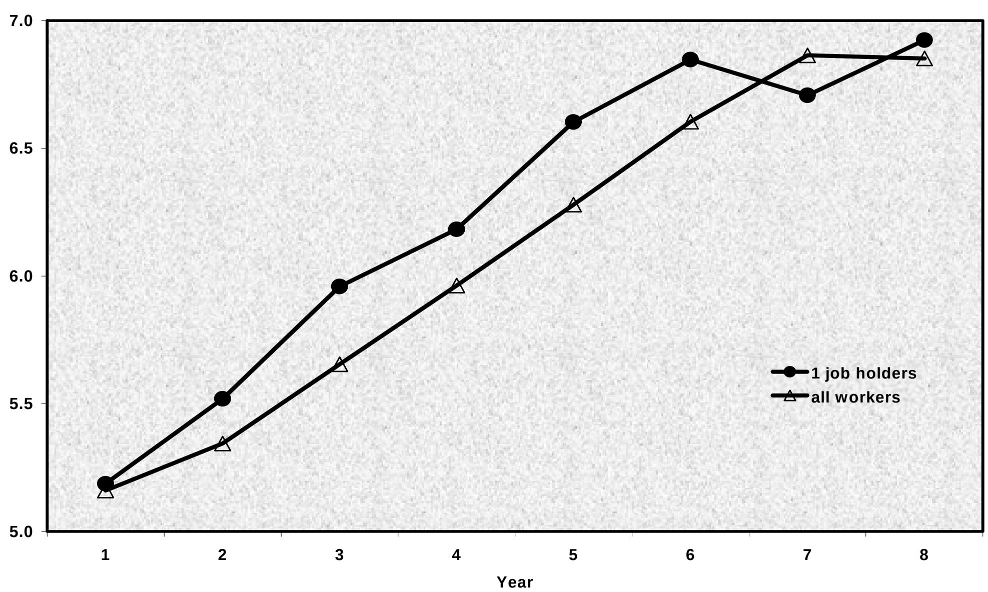
Based on the NLSY sample, averaged over one-year periods. Job-to-job transition rate defined as the number of workers who move to a different job next quarter divided by the number of workers employed in the current quarter.

Figure 3.5 Number of Jobs Frequency



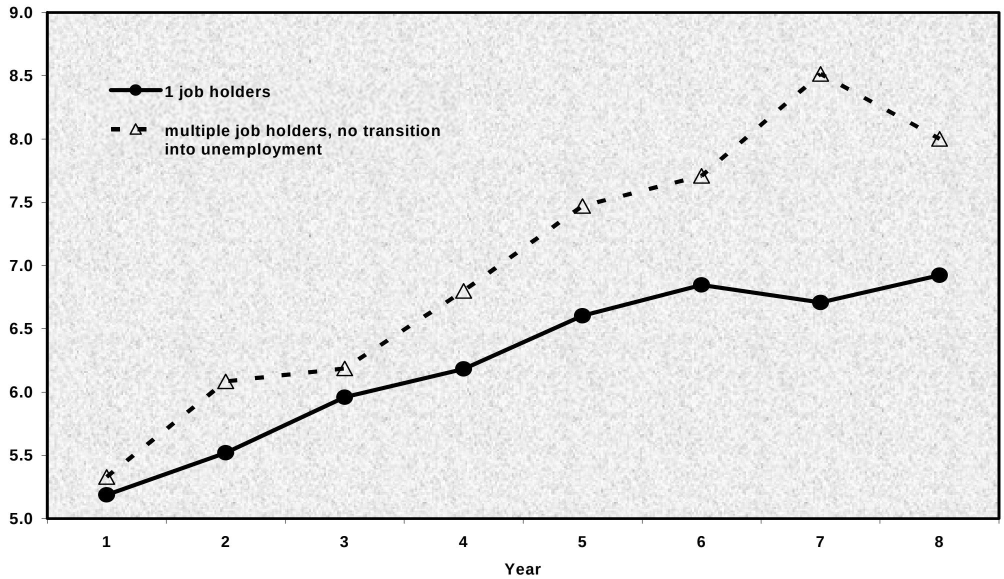
Source: NLSY

Figure 3.6 Mean Wage Rate for All Workers and for Single-Job Holders



Source: NLSY. Sample consists of 467 workers. The time series entitled "1 job holders" consists of workers who work at only one job during the entire 8 year span, and, are initially employed, or begin employment in the second quarter (41 workers out of 82 single-job holders). The mean wage rate is the real hourly wage, conditional on being employed, averaged over 1-year periods.

Figure 3.7 Mean Wages for Workers who Never Return to Unemployment



Source: NLSY. Sample consists of 467 workers. The time series entitled "1 job holders" consists of workers who work at only one job during the entire 8 year span, and, are initially employed, or begin employment in the second quarter (41 workers out of 82 single-job holders). The multiple job holders are workers who are initially employed or begin employment after one quarter, hold at least two jobs, and never return to unemployment during the 8-year span. The mean wage rate is the real hourly wage, conditional on being employed, averaged over 1-year periods.

Table 3.2 Descriptive statistics. Average wage rate, average experience and tenure (in quarters), average number of jobs

Year	Average wage	Average experience	Average job tenure
1	5.16	1.22	0.82
2	5.34	3.62	2.17
3	5.65	6.30	3.45
4	5.96	9.21	4.64
5	6.28	12.31	5.80
6	6.60	15.54	6.97
7	6.86	18.86	8.19
8	6.85	22.18	9.47

Table 3.3 Descriptive statistics. The average wage rate on the first job out of the initial unemployment spell in the first 3 years and the number of workers who start their first job on that period).

Period	Average wage	# of workers
1	4.88	45
2	4.70	30
3	4.48	38
4	5.17	27
5	4.14	17
6	4.94	10
7	4.26	19
8	4.68	10
9	6.07	5
10	5.59	8
11	5.02	9
12	3.91	10

Table 5.1 The data moments and the estimated moments in the main model

a. Mobility moments

Moment / Quarter	Q1 : Q8	Q9 : Q16	Q17 : Q24	Q25 : Q32
Mean unempl. hazard rate (data)	0.161	0.115	0.051	0.042
Mean unempl. hazard rate (model)	*0.166*	*0.131*	*0.111*	*0.107*
Mean job-to-job transition rate (data)	0.060	0.047	0.044	0.041
Mean job-to-job transition rate (model)	*0.065*	*0.053*	*0.046*	*0.043*
Mean E-to-UE transition rate (data)	0.094	0.068	0.048	0.042
Mean E-to-UE transition rate (model)	*0.132*	*0.062*	*0.048*	*0.042*

b. Wage moments

Moment / Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Mean wage (all)								
Data	5.17	5.35	5.66	5.97	6.28	6.60	6.86	6.85
Model	*5.09*	*5.50*	*5.79*	*6.02*	*6.20*	*6.34*	*6.45*	*6.54*
Mean wage (single-job)								
Data	5.19	5.82	6.20	6.47	7.17	7.05	7.03	7.05
Model	*5.49*	*6.02*	*6.36*	*6.57*	*6.71*	*6.80*	*6.86*	*6.91*

Figure 5.1 Model Fit - Percentage of workers not employed

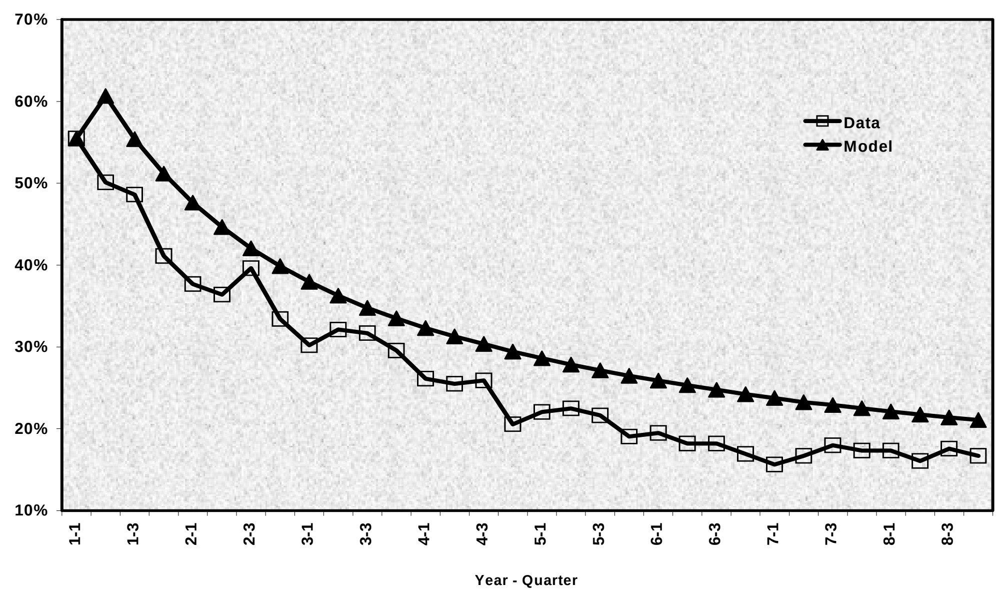


Table 5.2 Coefficients of the Mincer regression

Without tenure effects: $\log w_t^i = \beta_0 + \beta_1 EX_t^i + \beta_2 \left(EX_t^i\right)^2 + \varepsilon_t^i$, where ε_t^i is assumed i.i.d. accross t and i. (EX_t^i denotes the number of periods of employment for worker i, up to and including time t).

With tenure effects: $\log w_t^i = \beta_0 + \beta_1 EX_t^i + \beta_3 \left(EX_t^i\right)^2 + \beta_4 TE_t^i + \beta_2 \left(TE_t^i\right)^2 + \varepsilon_t^i$, where TE_t^i denotes the number of periods of employment worker i has registered on the current job.

	$\widehat{\beta}_0$	$\widehat{\beta}_1$	$\widehat{\beta}_2$	$\widehat{\beta}_3$	$\widehat{\beta}_4$
Data	1.477	0.092	-0.004	-	-
Model	*1.5884*	*0.0994*	*-0.008*	-	-
Data	1.467	0.051	0.000	0.294	-0.152
Model	*1.5884*	*0.0874*	*-0.007*	*0.087*	*-0.033*

Table 5.3 Conditional mobility

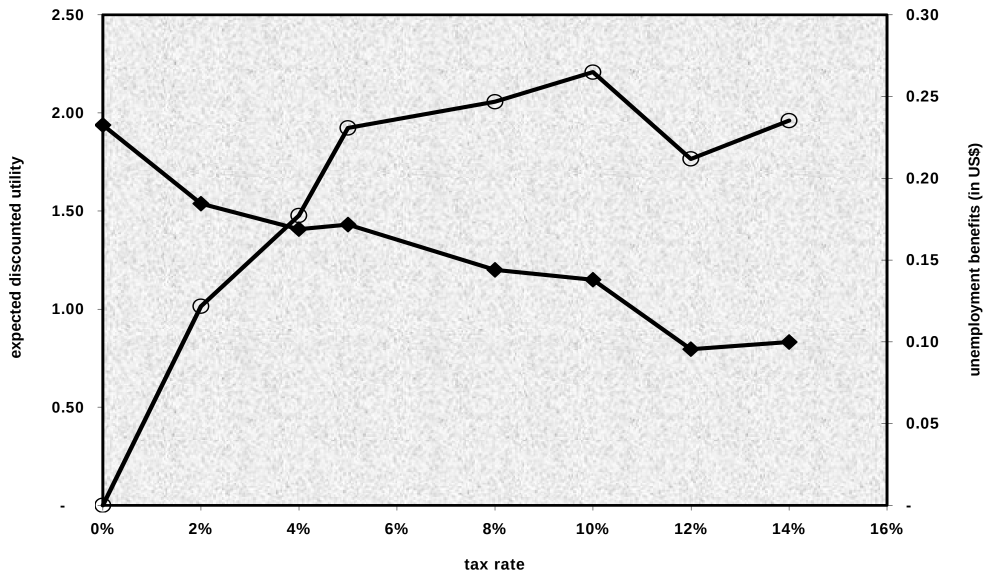
a. Probability of changing jobs conditional on the wage rate (in percentage points).

Wage rate	< 4	4 - 5	5 - 6	6 - 7	> 7
Data	7.39	5.15	3.84	3.37	3.68
Model	*11.07*	*7.01*	*3.18*	*4.34*	n/a

b. Probability of an employed worker becoming unemployed, conditional on the wage rate (in percentage points)

Wage rate	< 4	4 - 5	5 - 6	6 - 7	> 7
Data	11.41	6.80	4.40	4.00	3.54
Model	32.25	6.01	2.95	2.73	n/a

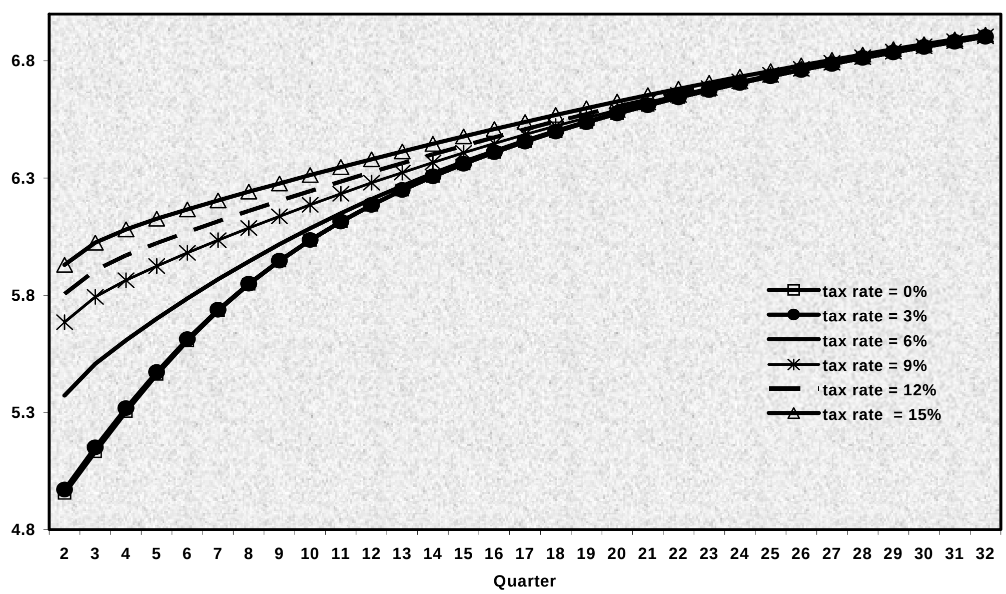
Figure 6.1 The Estimated Optimal Level of Unemployment Benefits



The expected discounted utility (normalized) is estimated from the model baseline estimates (see section 5.2).

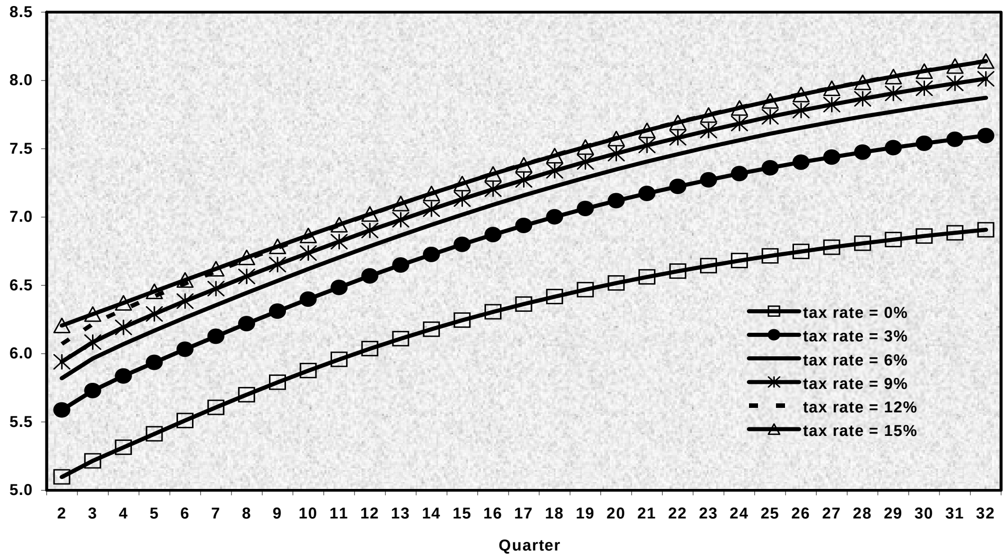
Tax rate chosen as a free parameter and the benefit level balances the budget over the 8-year period.

Figure 6.2 Mean Wage Conditional on Employment (constant experience model)



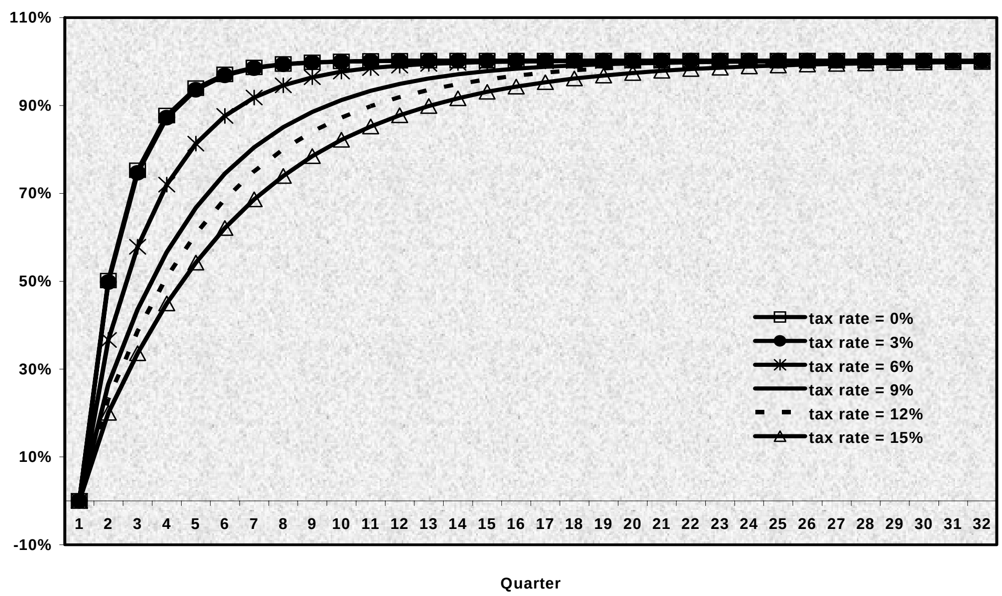
Using the model estimates and imposing $\nu = 0, \alpha = 1, \delta = 0$. Benefits chosen such that the budget equation balances over the 8-year period.

Figure 6.3 Mean Wage Conditional on Employment (the model with no search on-the-job)



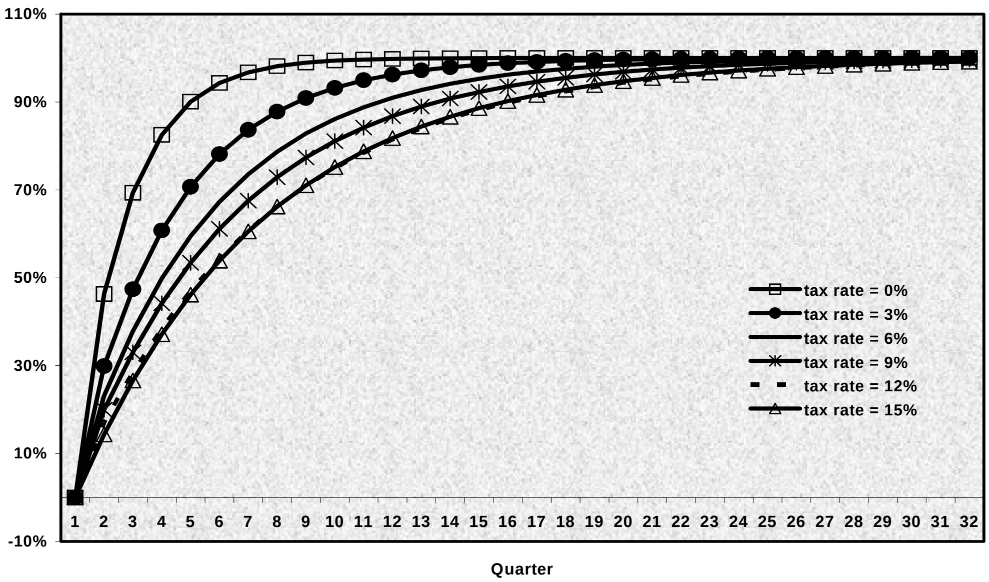
Using the model estimates and imposing $\lambda_1 = 0$. Benefits chosen such that the budget equation balances over the 8-year period.

Figure 6.4 Employment Rate (constant experience model)



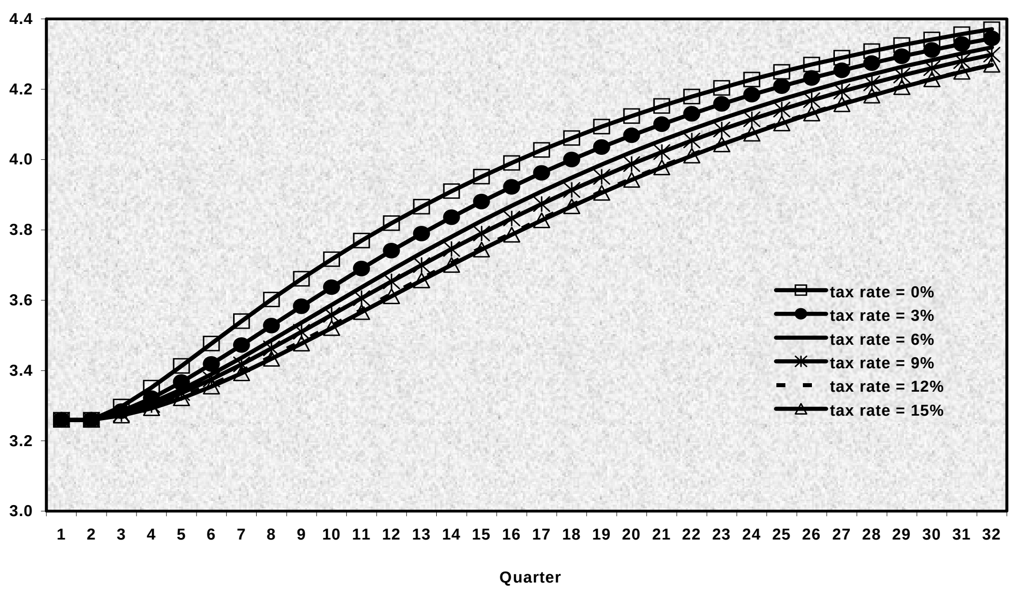
Using the model estimates and imposing $\nu = 0, \alpha = 1, \delta = 0$. Benefits chosen such that the budget equation balances over the 8-year period.

Figure 6.5 Employment Rate (the model with no search on-the-job)



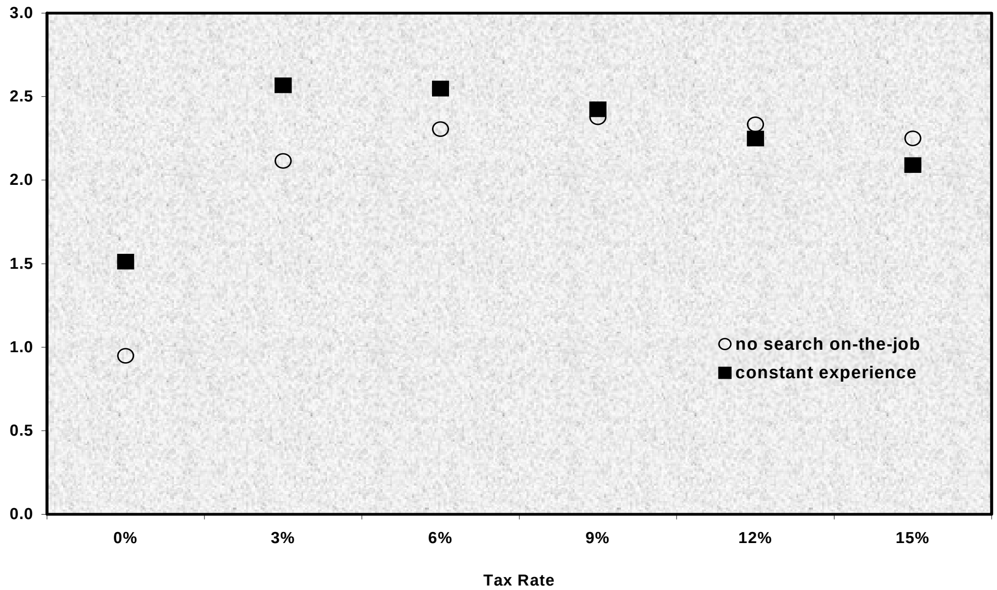
Using the model estimates and imposing $\lambda_1 = 0$. Benefits chosen such that the budget equation balances over the 8-year period.

Figure 6.6 Experience level (the model with no search on-the-job)



Using the model estimates and imposing $\lambda_1 = 0$. Benefits chosen such that the budget equation balances over the 8-year period.

Figure 6.7 Expected Discounted Utility



Using the model estimates and imposing $\lambda_1 = 0$ for the model with no search on-the-job and $\nu = 0, \alpha = 1, \delta = 0$, respectively, for the model with constant experience. Benefits chosen in each model such that the budget equation balances over the 8-year period.