Job Search and Asset Accumulation under Borrowing Constraints

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Abstract.- This paper explains the effects of asset accumulation and borrowing constraints on employment dynamics. I propose a model of job search and savings in which the unemployed maintain their consumption by running down their assets, while the employed save to buffer against future unemployment spells. Furthermore, variations in savings account for decreasing reservation wages during unemployment spells and for quits to unemployment. I fit this model to data from the National Longitudinal Survey (1979-cohort) and find that borrowing constraints are significant. More initial assets or more access to credit raises wages for several periods after High School graduation.

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1 Introduction

The main purpose of this paper is to determine the effects of asset accumulation and imperfect capital markets on employment dynamics. I develop and estimate a model of job search and savings which replicates the main observed trends of assets, employment transitions and wages. I find that asset holdings affect job search outcomes by allowing wealthier seekers to be more selective and wait for jobs that offer higher wages. In particular, an increase of \$5,000 dollars in initial assets raises accepted quarterly wages by \$800 in the first quarter after graduation and by lower amounts several periods afterwards. I also find that borrowing constraints are relatively tight, between 4 and 14% of the natural borrowing constraint, and that access to credit has an important effect on labor market outcomes: were borrowing constraint half of the natural limit, wages in the first quarter after graduation would raise by \$900 and remain higher for several periods.

In this paper, given their asset holdings both employed and unemployed agents decide on a level of consumption and a job acceptance policy, subject to a borrowing constraint that is parameterized as a fraction of the natural borrowing limit. Additionally, the employed experience wage growth while working for the same employer. This model has the following implications: i) reservation wages are increasing in assets; ii) during unemployment spells agents decumulate assets and reduce their wage aspirations; iii) during employment spells agents save to hedge against future periods of unemployment; and iv) increases in assets during employment spells account for quits to unemployment. Thus, variations in savings underlie the observed patterns of labor market variables such as increasing hazard rates and decreasing accepted wages while unemployment, and quits to unemployment.

The asset data used in this analysis come from the National Longitudinal Survey (youth cohort). Although there are clearly measurement errors, these data exhibit systematic features. As seen in Table 1, white male High School graduates, who did not attend college, accumulate assets after leaving school. From year 3 to year

9 after graduation, they increase their assets from \$6,000 to \$13,300. In the same period the percentage of agents with more than \$10,000 increases from 20% to 43%, while the fraction of people that are unemployed or working part time decreases from 18% to 9% and average quarterly wages increase from \$3,400 to \$4,500. Asset accumulation does accompany the increase in labor market activity that occurs after these individuals leave high school. Table 2 shows the relationship between saving behavior and employment transitions. Becoming or staying unemployed is associated with a decumulation of assets, while becoming or staying employed, or switching from one employer to another, is associated with an increase in asset holdings. Those who remain unemployed between two calendar quarters run down their assets by \$1,600, while those who remain working for the same employer increase their assets by \$1,500 per quarter. These comovements, while not surprising, are systematic and informative about the credibility of the asset data.

In standard job search models[2] individuals are wealth maximizers residing in a world of perfect capital markets where the processes of asset accumulation and job search are unconnected. However, if people are not able to borrow freely in the official credit market, they can only self-finance the out-of-pocket cost of search for a period of time that depends on their financial resources (Mortensen 1986), that is, asset holdings influence their search horizon. Econometric studies of the standard job search process are thus based on the assumption of either an infinite search horizon with perfect capital markets or an exogenously given search horizon (Flinn and Heckman 1982*a*, 1982*b*, Kiefer and Neumann 1979, Meyer 1990, Wolpin 1987, 1992).

Danforth (1979), using a model of utility-maximizing job search, analyzed in detail the role of asset endowments on an individual's optimal job search strategy. In his setup, only the unemployed look for a job, receiving wage offers from a non-degenerate distribution; the employed do not search nor do they become unemployed. In these conditions, agents run down their wealth in both employment states. Since

[2] See the models surveyed by Lippman and McCall (1976) and Mortensen (1986).

his seminal paper, several utility-maximizing job search models have been proposed, mostly to assess the role of unemployment insurance in job search and consumption and of job search in business cycles.[3] In recent years, several authors have done empirical research following Danforth's framework.[4] Stancanelli (1999) and Bloemen and Stancanelli (2001) using Dutch data find that more wealth increases reservation wages and reduces transitions from unemployment to employment. Similarly, Algan et al. (2002) using French data show that more wealth decreases unemployment duration and increases the probability of quits to unemployment. Along these lines, Lentz and Tranæs (2001) propose a model that links asset holdings to job search by the choice of search intensity, similar to Costain's (1997), and show theoretically that assets have an ambiguous effect on search intensity. Using Danish data they find that search intensity exhibits positive duration dependence over the unemployment spell, which suggests that wealth has a negative effect on job search.

The model proposed in this paper is the first to generalize Danforth's canonical model, characterized by a non-degenerate wage offer distribution, savings, and no choice of search intensity, to allow for on-the-job search, wage growth, retirement, and a parametric borrowing limit that is estimated. With these features, this job search model is able to generate realistic trajectories and distributions of employment transitions, assets and wages over the life cycle.

To recover the behavioral parameters of the model I use two estimation procedures, maximum likelihood (ML) and simulated method of moments (SMM), and contrast their results. The first method is surveyed by Rust (1988) and Eckstein and Wolpin (1989); it consists of using the numerical solution of the dynamic programming problem as an input to constructing probability statements for observed assets,

[3] See Flemming (1978), Hansen and Imrohoroglu (1992), Andolfatto (1996), Blundell, Magnac and Meghir (1997), Costain (1997), Hopenhayn and Nicolini (1997), Acemoglu and Shimer (1999), Marimon and Zilibotti (1999), Gomes, Greenwood and Rebelo (2001), Lentz (2001), Bertola (2002), Pissarides (2002), Browning, Crossley and Smith (2002), and Joseph and Weitzenblum (2003).

[4] Notable empirical studies on consumption during unemployment, though not on job search, were done by Hamermesh (1982) and by Dynarski and Sheffrin (1987), who study consumption patterns during unemployment spells.

wages and employment transitions and integrate them into a maximum likelihood estimation procedure. The second method minimizes the average distance between the sample moments and the moments predicted by the dynamic model. Accounting for differences in initial assets and assuming specific utility, wage offer distribution, and wage growth functions I recover the parameters of the search model and use them to evaluate two regime changes: displacing the initial asset distribution and relaxing borrowing constraints.

The remainder of the paper is organized as follows. Section 2 describes the model and highlights its main implications for asset accumulation and employment dynamics; Section 3 explains the selection of the sample and the descriptive statistics; Section 4 details the estimation procedure; Section 5 presents the results of the estimation, and Section 6 discusses regime changes based on the estimated parameters of the model. Section 7 summarizes the main conclusions of the paper.

2 The Model

Consider an individual with a period-by-period utility function $U(\cdot)$ over consumption who seeks to maximize expected lifetime utility without bequesting. This agent lives for T_F quarters but works for T quarters, after which he retires and lives off his savings. Throughout his working lifetime he can be unemployed, in which case with probability λ^e he receives one wage offer x drawn from the known wage offer distribution $F(\cdot)$, $x \in [\underline{w}, \overline{w}]$, $0 < \underline{w} < \overline{w} < \infty$; or he can be employed and be laid off with probability θ and receive a wage offer with probability λ^e, drawn from the same distribution $F(\cdot)$. While unemployed, he becomes employed if he receives and accepts a wage offer; otherwise he remains unemployed. While employed, he can experience the following transitions:

If he is not laid off and receives a job offer, he can accept it and switch to a new job, reject it and stay in the current job, or reject it to quit his current job and become unemployed.

If he is not laid off and does not receive a job offer, he has to decide between staying in the job or quitting to unemployment.

If he is laid off and receives an offer, he can accept it and switch to a new job, or reject it an become unemployed.

If he is laid off and does not receive an offer, his only option is to become unemployed.

During his working life the agent receives transfers b when unemployed, which include non-labor income, like family transfers, plus unemployment compensation net of out-of-pocket search costs.[5] When employed the agent experiences wage growth due to specific human capital accumulation. His current wage $w(\omega, k_t)$ depends on the initial wage draw ω and the number of periods he has been working for the same employer k_t. Specific human capital evolves deterministically until reaching an upper bound: $k_{t+1} = \min\left(k_t + 1, \overline{k}\right)$.

In each period, given his employment state and his current assets A_t, the agent determines his level of consumption C_t^u and C_t^e or, equivalently, his desired level of assets for the next period A_{t+1}^u and A_{t+1}^e. Initial assets A_0 are inherited, so they are not the product of an earlier accumulation of assets. The rate of return r is the same for saving and borrowing and is constant. The subjective discount factor is $\beta \in (0, 1)$. There is no restriction for transferring resources across periods through saving; assets, however, cannot be lower than a time-dependent level B_t. Under a free capital markets the individual can borrow as much as he can pay back with probability one, that is, there is a Hakansson-Miller or 'natural' borrowing limit (Hakansson 1970, Miller 1974, Ljungqvist and Sargent 2000).[6] Because his lowest

[5]Search costs and choice of search intensity can be explicitly included in this model. The identification of these additional parameters is, however, not feasible given the available data.

[6]Paying back with certainty can be caused by lenders being fully risk averse and unwilling to share risks with borrowers. As discussed by Grossman, Levhari and Mirman (1979), if the borrowing limit is the expected lifetime income, bankruptcy has to be possible, which cannot happen with utility

possible income level is b, and once retired he does not receive any income, this borrowing limit is $\widetilde{B}_t = -\sum_{s=t}^{T} b\frac{1}{(1+r)^{T-s}} = -b\left(\frac{1+r}{r}\right)\left(1-\frac{1}{(1+r)^{T-t+1}}\right)$. With a utility function satisfying the Inada condition $\lim_{C\to 0} U(C) = \infty$, he will not run down his assets below $\widetilde{B}_t$, because $\widetilde{B}_t + b - \frac{\widetilde{B}_{t+1}}{1+r} = 0$, so any constraint $B_t < \widetilde{B}_t$ is redundant. The individual is said to face borrowing constraints whenever he is only allowed to borrow below his certain capacity of repayment, i.e., $B_t > \widetilde{B}_t$. A parameter s measures the tightness of the borrowing constraint as a fraction of the 'natural' borrowing limit, that is, $B_t = s\widetilde{B}_t$, $s \in [0,1]$.

The present discounted utility of a retired agent V_t^R, $t = T+1, ..., T_F$, depends on asset holdings A_t:

$$V_t^R(A_t) = \max_{\{A\}_{s=t+1}^{T_F}} \sum_{s=t}^{T_F} \beta^{s-t} U\left(A_s - \frac{A_{s+1}}{1+r}\right),$$

where, in the absence of bequest motives, $A_{T_F+1} = 0$. With agents saving voluntarily for retirement with full control over their pension funds, the dynamic problem becomes 'a cake-eating problem.'[7]

Expected lifetime utility in the unemployment state at time t, V_t^u, is characterized by asset holdings A_t:

$$\begin{aligned} V_t^u(A_t) \quad = \quad & \max_{A_{t+1}^u \geq B_{t+1}} \left\{ U\left(A_t + b - \frac{A_{t+1}^u}{1+r}\right) \right. \\ & \left. +\beta\left[\lambda^u \int \max\left[V_{t+1}^e(A_{t+1}^u, x, 0), V_{t+1}^u(A_{t+1}^u)\right] dF(x) + (1-\lambda^u)V_{t+1}^u(A_{t+1}^u)\right]\right\} \end{aligned}$$

functions satisfying the Inada condition. Moreover, incorporating the full set of Arrow-Debreu contingent contracts would require allowing for default and dealing with problems of adverse selection or moral hazard which are beyond the scope of this paper.

[7] The institutional mechanisms of a pension system (characterized by schemes of contribution during working lifetime and pensions during retirement) are beyond the goal of this paper. This highly stylized analysis, however, will prove able to generate savings for life cycle motives.

In the employment state, expected lifetime utility V_t^e at time t depends on asset holdings A_t, wage ω and tenure k_t:

$$\begin{aligned} V_t^e(A_t, \omega, k_t) \quad = \quad & \max_{A_{t+1}^e \geq B_{t+1}} \left\{ U\left(A_t + w\left(\omega, k_t\right) - \frac{A_{t+1}^e}{1+r} \right) \right. \\ & + \beta \left[(1-\theta)(\lambda^e \int \max\left[V_{t+1}^e(A_{t+1}^e, x, 0), V_{t+1}^e(A_{t+1}^e, \omega, k_{t+1}), V_{t+1}^u(A_{t+1}^e)\right] dF(x) \right. \\ & + (1-\lambda^e) \max\left[V_{t+1}^e(A_{t+1}^e, \omega, k_{t+1}), V_{t+1}^u(A_{t+1}^e)\right]) \\ & \left.\left. + \theta \left(\lambda^e \int \max\left[V_{t+1}^e(A_{t+1}^e, x, 0), V_{t+1}^u(A_{t+1}^e)\right] dF(x) + (1-\lambda^e) V_{t+1}^u(A_{t+1}^e) \right) \right] \right\} \end{aligned}$$

We have thus a dynamic problem (DP) with a finite horizon T and a 'salvage value,' the value of being retired: $V_t^u(A_t) = V_t^R(A_t)$, $V_t^e(A_t, \omega, k_t) = V_t^R(A_t)$, at $t = T+1$. Two policy rules $A_{t+1}^u(A_t)$ and $A_{t+1}^e(A_t, \omega, k_t)$ solve this problem. Whether the individual is employed or unemployed, there exists a reservation wage that indicates the lowest acceptable wage to start working for a new employer, that is, $\omega_t^*(A_t) = \{\omega | \; V_t^u(A_t) = V_t^e(A_t, \omega, 0)\}$. Because of on the job search and wage growth there is a second reservation wage that emerges from the comparison between the value of switching to a new employer and the value of staying at the current job and accumulating human capital: $v_t(A_t, \omega, k_t) = \{v | \; V_t^e(A_t, v, 0) = V_t^e(A_t, \omega, k_t)\}$.

Since the optimal solution to the DP problem does not admit an analytical expression, I compute a numerical approximation to the value functions and to the policy rules. This procedure entails discretizing the continuous state variables into a grid of points and assuming specific functional forms: a constant relative risk aversion (CRRA) utility function $U(C) = \frac{C^{1-\gamma}-1}{1-\gamma}$, where γ is the coefficient of risk-aversion, a truncated lognormal wage offer distribution $\ln x \sim N(\mu, \sigma^2 | \ln \underline{w}, \ln \overline{w})$, and a wage function $w(\omega, k_t) = \omega \exp(\alpha_1 k_t + \alpha_2 k_t^2)$. Appendix A1 describes in greater detail the discretization and the solution technique.

Figure 1 illustrates the policy rules at period 1 under the assumption that there is no on-the-job wage growth.[8] Figure 1a and 1b present cross sections of A^u and A^e as a function of A. In the first figure, unemployed agents decumulate assets monotonically until hitting the borrowing limit, that is, they use their accumulated assets to maintain their consumption and search for a job. The next figure shows that employed agents accumulate assets until reaching some steady state level; thereby they are hedging against future unemployment spells. Figure 1c depicts the reservation wage $w_1^*(A)$ and expected accepted wages $E(x \mid x \geq w_1^*(A))$ as a function of assets. They are both clearly increasing in assets, which means that wealthier agents are more selective, and have higher accepted wages. These policy rules imply that during unemployment spells agents decumulate their assets, decrease their reservation wages and increase their hazard rates, whereas during employment spells they build up their assets and increase their reservation wages. In this manner, variations in assets influence labor dynamics and create time dependence in employment states and wages.

Figure 1d illustrates how quits to unemployment can happen in this model.[9] An agent with wealth A and employed at wage $w_1^*(A)$ enters next period with wealth $A_1^e(A_t, w_1^*(A))$, and his reservation wage becomes $w_2^*(A_1^e(A_t, w_1^*(A)))$. For low asset levels, if this new reservation wage exceeds his current wage and there is no acceptable wage offer from another employer, he will voluntarily leave his current job to become unemployed. This is equivalent to saying that quits to unemployment can happen if the reservation wage allows agents to accumulate assets: $A_1^e(A_t, w_1^*(A)) > A$. This

[8] In that case, the value functions can be expressed as $V_t^u(A)$ and $V_t^e(A, w)$, and the policy rules as $A_t^u(A)$, $A_t^e(A, w)$ and $w_t^*(A)$. Table 3 reports the parameter values used to compute these policy rules.

[9] Unlike quits to switch employer, usual in models with on-the-job-search (Burdett 1978), explanations for quits to unemployment are less frequent in the literature. One explanation is that workers may take jobs without knowing their true wage; once wages are revealed to be low, they quit to unemployment (Jovanovic 1979). Another argument, which explains the observed trend that quits are procyclical, is that an economic boom changes wage offer distributions or arrival rates such that a worker finds profitable to quit to search while unemployed (Jovanovic 1987, Lippman and Mamer 1989). Finally, in a finite horizon model in which wages and arrival rates depend on work experience and tenure, people quit because the value of investing in working decreases over time (Wolpin 1992).

incentive to quit exists if the wage offer rate is considerably higher while unemployed than while employed. An agent with little wealth and a badly paid job accumulates wealth and finds that his current job is no longer acceptable, for he can search for better jobs while unemployed with a higher probability of receiving wage offers. Accumulating assets and quitting to unemployment are thus part of the whole search strategy for attaining higher wages.[10]

I also use the policy rules to simulate the employment, wages and asset trajectories for individuals with zero initial assets and with $10,000 worth of initial assets. Figure 2 shows the time paths for assets, consumption, wages, and unemployment rate for both types of individuals from High School graduation to retirement. Figure 2a shows that in the years immediate after graduation wealthy agents decumulate while poor agents accumulate; then, in their mid-life, both maintain their assets level stable, and, finally, they accumulate intensively in the years prior to retirement.[11] The difference in initial wealth between both types of individuals reduces over time but persists for more than 60 quarters after graduation. Consumption, shown in Figure 2b, increases over time at the beginning of the employment career and is higher for wealthier individuals; however, it reduces slightly in the years prior to retirement. Figure 2c shows that wealthier individuals start off with higher wages, but, as their reservation wages go down during the first and longer unemployment spell, average wages initially decrease for a few quarters. However, wages increase systematically over time and only decrease after period 130, because reservation wages decrease at the end of the working lifetime. Figure 2d reports the unemployment rate over time, which decreases substantially in the first quarters after graduation, remains relatively constant over time, and decreases at the end of the working lifetime.

[10] Unlike in dynamic models of consumption and labor supply where agents decide on their income directly by choosing the number of hours worked (Heckman and MaCurdy 1980, MaCurdy 1981), in job search models agents decide indirectly on their income through a stopping rule.

[11] This pattern of asset accumulation prior to retirement coincides with the one explained by Rust, Bushinsky and Benítez-Silva (2003), who use a model with contributions during the working lifetime and pension schemes.

Table 3 presents a summary of variations of several variables at quarters 1, 20, and 40 produced by a variation of each parameter at a time for individuals who start off their careers with zero assets. Selected variables are unemployment rates, assets, wages, consumption, saving rates, welfare, measured as the average cumulative discounted utility received so far. It also shows quits to unemployment as a percentage of employed agents who become unemployed. A higher value of unemployment transfers raises reservation wages, thereby increasing unemployment rates, wages, consumption, and welfare. It also reduces the need for a buffer stock, so assets go down, but, as wages are higher, saving rates decline as well. Increases in λ_u or λ_e reduce unemployment rates and increase wages, consumption, saving rates, and welfare. However, a higher λ_u increases assets, suggesting that the effect of higher wages dominates over the effect of a less painful unemployment. By contrast, a higher λ_e decreases assets, which implies that the effect of faster job-to-job transitions that make agents less afraid of becoming unemployed is stronger than the effect of higher wages. Higher layoff rates produce higher unemployment rates and lower wages, consumption and welfare, but an increase in asset holdings, for it increases the need to buffer against a more likely unemployment spell. A better wage offer distribution, characterized by a higher mean or variance of logwages, implies higher unemployment rates and wages, but also more wealth and more consumption, with a lower saving rate. Similar effects are obtained by faster on-the-job wage growth, which produces a more persistent decline in saving rates.

More risk averse agents are less selective in their job search and, accordingly, have lower unemployment rates, wages, and consumption, but also more wealth, as they are more afraid of future unemployment spells. On the contrary, agents with more access to credit are more selective and have higher unemployment rates, wages, and welfare, but lower assets, as they rely more on credit rather than on their own buffer stock. They also have lower consumption, as their assets are lower and they receive lower interest income.

Quits to unemployment deserve particular attention. As they are generated by better conditions to search for a job while unemployed, a higher λ^u increases these quits, while a higher λ^e reduces them. With a higher layoff rate individuals quits less to unemployment, for they can just wait to be laid off. Similarly, higher unemployment transfers, a better wage offer distribution and faster wage growth reduce the incentive for quitting to unemployment. Finally, more risk averse agents quit less to unemployment, whereas agents with more access to credit quit more.

This comparative statics exercise explains the effect of the parameters of the model on the observables; the next sections explain the opposite: how to use the data to recover the behavioral parameters.

3 Data

The data come from the National Longitudinal Survey of Labor Market Experience - Youth Cohort (NLSY). This survey is a national stratified sample of 12,686 individuals between 14 to 21 years old in January, 1979, who have been interviewed annually from 1979 onwards. It provides data on personal characteristics, household composition, educational status and attainment, military experience, labor market activity and transitions, detailed week by week work histories, income and assets. It is possible to construct a complete weekly work history of an individual from year 1978 onwards.

Since the theoretical model corresponds more closely to a male labor force, does not include the decision to attend college nor to join the military, out of the total number of respondents, I have selected High School white male graduates born after December 31, 1960, who never went to college nor had any type of military experience and for whom there are assets data. Individuals born before 1961 are excluded from the sample, because a complete employment history cannot be constructed for them, as their careers started before 1978. White males are the modal group in the NLSY. There were 212 individuals who satisfied all the selection criteria; in the final sample each of them has 40 quarterly observations for assets, wages, employment status, and the reason for leaving the current employer.[12] Assets are only observed annually since year 1985. Appendix A2 provides detailed explanations of these variables.

Table 4 presents summary statistics for the duration of the first unemployment spell, employment transitions, quits, wages and assets. The first unemployment spell of these people lasts on average 2.52 quarters. Out of the total unemployed 42% become employed in the next quarter, whereas 6% of the employed become unemployed in the next quarter, and about 9% of the employed change employers in the next quarter. It is also clear that an important proportion of people voluntarily abandon their current job to work for another employer or to become unemployed. At least 32% of the employed who become unemployed did so because of voluntary reasons. Average wage growth is 2.2% per quarter. It is, however, clear that changing employers is one of the main sources of wage increase: ages increase by 15% on average when agents change employers. Asset accumulation is relatively fast: assets grow on average 3.25% per quarter.

As shown in Tables 1 and 2, asset accumulation and labor dynamics exhibit systematic comovements, which are in line with the predictions of the theoretical model. Accumulation of assets and work experience implies also a change in the composition of assets, as presented in Table 5. Wealthier people tend to have a higher proportion of their assets in the form of residential property, business, farms or other form of property. Among the people with no more than 6 years after graduation, those with no more than $10,000 have only 7% of their wealth in residential property, while people with more than $30,000 have 23% of their wealth in the residential property. The proportion of wealth in the form of residential property increases over time: agents

[12] This sample selection is stringent and aims to reduce the adverse consequences of making inferences based on individuals with heterogeneous labor market environments. See Flinn (1986), and Wolpin (1987,1992) for examples of stringent data selections in structural estimations. In Rendon (2003), I use a larger sample which also includes black individuals and determine the effect of capital markets in black-white differences in labor market outcomes. The basic findings presented here are corroborated with that larger sample.

with more than 6 years after graduation and no more than \$10,000 hold about 16% of their wealth in residential property, while people with more than \$30,000, around 26% of their assets is held as residential property. The proportion of financial assets, the most liquid component of wealth, is decreasing and then increasing in wealth. In contrast, the percentage of business property and wealth shows a fairly clear positive correlation.[13] The proportion of wealth in the form of vehicles shows a very clear negative correlation with wealth level. Around half of the wealth of people with less than \$10,000 is represented by the car. In short, poor people are owners of vehicles, while wealthy people are owners of houses, financial assets and businesses.[14] A matter of future research is to relate these changes in the composition of assets to labor market dynamics.

4 Estimation

Since introducing assets into the job search model affects reservation wages and thus creates time dependence in employment states and wages, it is interesting to contrast a method that is constructed at the longitudinal level, the ML estimation, with one that privileges the cross-sectional dimension of the panel, the SMM estimation. Both procedures use the policy rules of the dynamic programming problem as an input in the construction of a function that is optimized over the behavioral parameters.

4.1 Likelihood function

This procedure uses the probability statements of each individual transition in employment status, wages, and assets to construct a likelihood function. The estimation starts at the period when assets are first observed, t_0, that is, data between 1978

[13] Using a static framework, Evans and Jovanovic (1989) find that having more assets under borrowing constraints increases the probability that a worker starts a business.

[14] These patterns in the composition of assets are also shown by Sobol (1979), Jianakoplos, Menchik and Irvine (1989), Blau and Graham (1990), Wolff (1994), and Gittleman and Wolff (2004).

and 1985 are not used. The log-likelihood function is the sum of the individuals' log-likelihood which is the density for the sequence of observables, conditional on the observation at t_0 and the parameters Θ:

$$\ln \mathcal{L}(\Theta) = \sum_{i=1}^{N} \ln \mathcal{L}_i(\{Z_{it}\}_{t=t_0+1}^{T_i} \mid Z_{it_0}\Theta).$$

The observed variables are $Z_{it} = \left\{A_{it}^{obs}, w_{it}^{obs}, d_{it}, h_{it}, l_{it}\right\}$, that is, assets, wages, employment status (unemployed or employed: $d = \{u, e\}$), employer, ($z = 1$, employer change; or $z = 0$, otherwise), and the reason for leaving the current employer ($l = 1$, layoff; or $l = 0$, otherwise). Work experience k depends solely on d and z. Let wages net of work experience ω^{obs} be such that $w^{obs} = w\left(\omega^{obs}, k\right)$, that is, $\ln \omega^{obs} = \ln w^{obs} - \alpha_1 k - \alpha_2 k^2$. The individuals' likelihood contribution can be decomposed into a product of conditional and marginal densities for each transition denoted by $g_t(A_{t+1}, \omega_{t+1}|A_t, \omega_t)$. There are five possible employment transitions:

1. From Unemployment to Unemployment, $d_t = 0$, $d_{t+1} = 0$:

$$g_t(A_{t+1}, 0|A_t, 0) = \lambda^u F\left[\omega_t^*\left(A_{t+1}\right)\right] + (1-\lambda^u), \text{ if } A_{t+1} = A_{t+1}^u(A_t);$$

2. From Unemployment to Employment, $d_t = 0$, $d_{t+1} = 1$:

$$g_t(A_{t+1}, \omega_{t+1}|A_t, 0) = \lambda^u f(\omega_{t+1}), \text{ if } \omega_{t+1} \geq \omega_{t+1}^*\left(A_{t+1}\right) \text{ and } A_{t+1} = A_{t+1}^u(A_t);$$

3. From Employment to Unemployment, $d_t = 1$, $d_{t+1} = 0$, $z_{t+1} = 0$:

$$\begin{aligned} \text{Layoff, } l_t = 1: \quad g_t(A_{t+1}, 0|A_t, \omega_t) &= \theta[\lambda^e F\left[\omega_{t+1}^*\left(A_{t+1}\right)\right] + (1-\lambda^e)] \\ &\quad \text{if } A_{t+1} = A_{t+1}^e(A_t, \omega_t, k_t); \\ \text{No Layoff, } l_t = 0: \quad g_t(A_{t+1}, 0|A_t, \omega_t) &= (1-\theta)\left[\lambda^e F\left[\omega_{t+1}^*\left(A_{t+1}\right)\right] + (1-\lambda^e)\right], \\ &\quad \text{if } \omega_{t+1}^*\left(A_{t+1}\right) > v_t\left(A_{t+1}, \omega_t, k_{t+1}\right) \\ &\quad \text{and } A_{t+1} = A_{t+1}^e(A_t, \omega_t, k_t); \end{aligned}$$

4. Same employer, $d_t = 1$, $d_{t+1} = 1$, $z_{t+1} = 0$:

$$g_t(A_{t+1}, \omega_t|A_t, w_t) = (1-\theta)[\lambda^e F(v_t) + (1-\lambda^e)], \qquad \begin{array}{l} \text{if } v_t\left(A_{t+1}, \omega_t, k_{t+1}\right) \geq \omega_t^*\left(A_{t+1}\right) \\ \text{and } A_{t+1} = A_{t+1}^e(A_t, \omega_t, k_t); \end{array}$$

5. Change employer, $d_t = 1$, $d_{t+1} = 1$, $z_{t+1} = 1$:

$$\begin{array}{lrcl} \text{Layoffs, } l_t = 1: & g_t(A_{t+1}, \omega_{t+1}|A_t, \omega_t) & = & \theta\lambda^e f(\omega_{t+1}), \text{ if } \omega_{t+1} \geq \omega^*_{t+1}(A_{t+1}) \\ & & & \text{and } A_{t+1} = A^e_{t+1}(A_t, \omega_t, k_t); \\ \text{No Layoff, } l_t = 0: & g_t(A_{t+1}, \omega_{t+1}|A_t, \omega_t) & = & (1-\theta)\lambda^e f(\omega_{t+1}), \\ & & & \text{if } \omega_{t+1} \geq \max([v_t(A_{t+1}, \omega_t, k_{t+1}), \omega^*_t(A_{t+1})] \\ & & & \text{and } A_{t+1} = A^e_{t+1}(A_t, \omega_t, k_t); \end{array}$$

where $k_{t+1} = \min\left(k_t + 1, \overline{k}\right)$. And $g_t(A_{t+1}, \omega_{t+1}|A_t, \omega_t) = 0$, if the corresponding condition is not met.[15]

Because these densities only account for one level of assets and for certain admissible values of wages, the estimation requires another source of randomness. Since there are justified reasons to believe that assets and wages are measured with errors, a way to make the estimation feasible is to define observed assets and wages as the model's predicted level plus a measurement error. Thus, $A^{obs}_t = A_t + \varepsilon_A$ and $\ln \omega^{obs}_t = \ln \omega_t + \varepsilon_w$, where ε_A and ε_w are normally distributed with zero mean and standard deviation σ_A and σ_w, respectively.

The joint density for a given sequence of observables is obtained from integrating over all of possible sequences of assets and wages, expressed as the product of the conditional densities over all transitions, conditional on the first observation at period t_0:

$$\begin{aligned} \mathcal{L}(\{Z_t\}^T_{t=t_{0+1}} \mid Z_{t_0}\Theta) &= \int \cdot\cdot \int \prod_{t=t_0}^{T} g_t\left(A_t, \omega_t | A_{t-1}, \omega_{t-1}\right) \frac{1}{\sigma_A}\phi\left(\frac{A^{obs}_t - A_t}{\sigma_A}\right) \\ &\qquad \frac{1}{\sigma_w}\phi\left(\frac{\ln \omega^{obs}_t - \ln \omega_t}{\sigma_w}\right) dA_t d\omega_t. \end{aligned}$$

where $g_0(A_{t_0}, \omega_{t_0}|A_{t_0-1}, \omega_{t_0-1}) = 1$. Computing this function requires a numerical approximation, which I compute by exploiting the discretization performed to solve the DP problem as described in Appendix A3. The parameters to estimate are $\Theta = \{b,\ \lambda^u,\ \lambda^e,\ \theta,\ \mu,\ \sigma,\ \alpha_1,\ \alpha_2,\ \gamma,\ s,\ \sigma_A,\ \sigma_w\}$. The interest rate r and the dis-

[15] To improve readability, I drop the individual subscript i and the parameter vector Θ, as well as employment status (expressed by a wage equal to zero), employer change, and layoffs.

count factor β are fixed at 0.015 and at 0.98, respectively. The iteration algorithm used to maximize this likelihood function is the Powell algorithm (see Press et al., 1992), which only requires function evaluations, not derivatives.

After recovering the behavioral parameters, one can use the data from period 1 until period t_0 one recover the initial asset distribution. The likelihood of observing these data, conditional on asset level A_0, or $Z_0 = \{A_0, 0, 0, 0, 0\}$, is $\mathcal{L}(\{Z_t\}_{t=1}^{t_0} \mid Z_0, \Theta)$, explained above. The density function of initial assets for each individual is thus

$$p\left(A_0|\Theta\right) = \frac{\mathcal{L}(\{Z_t\}_{t=1}^{t_0} \mid Z_0, \Theta)}{\int \mathcal{L}(\{Z_t\}_{t=1}^{t_0} \mid Z_0, \Theta) dA_0},$$

which is equivalent to a posterior distribution coming from of an uninformative prior distribution on initial assets and the observed paths of employment, layoffs, and wages. This distribution is necessary to simulate the model from the beginning of the individuals' employment careers.

4.2 Simulated Method of Moments

This procedure consists of simulating career paths for the whole sample and computing the parameters that minimize a measure of distance between the simulated and the observed moments. For each parameter set I compute the policy rules and the initial asset distribution, assuming that individuals are unemployed when they graduate from high school. Then, I generate simulated career paths for 212×10 individuals, that is 10 draws for each individual in the dataset. As a contrast to the previous estimation, based on the longitudinal dimension of the panel, the moments used in this estimation come the following period-specific cross-sectional choice distributions:

1. asset distribution (10 years $\times$ 5 moments),
2. wage distribution (10 years $\times$ 4 moments),
3. employment status (10 years $\times$ 2 moments),
4. employment transitions from unemployment (10 years $\times$ 2 moments),

5. employment transitions from employment (10 years $\times$ 3 moments),
6. layoffs from employment to unemployment (10 years $\times$ 2 moments), and
7. layoffs when changing employer (10 years $\times$ 2 moments).

The weighted average distance between sample moments and the simulated moments is computed using a diagonal matrix that equates this distance to a sum of the χ^2-statistics of the selected distributions (See Appendix A4). In this way, minimizing the weighted average distance between actual and predicted moments is thus equivalent to minimizing a goodness of fit measure. Consequently, this SMM estimation yields the best possible fit in the cross-sectional dimension of the data.

In addition to fixing r and β as in the previous estimation, I fix σ_A at 13,000, for there is only measurement error for assets at period t_0, when assets are first observed. The function is minimized using the Powell algorithm.

5 Results

5.1 Parameter Estimates

Both the ML and the SMM estimates and their corresponding standard errors are shown in Table 6. The ML estimate for net transfers while unemployed is higher than the SMM estimate, which matches higher predicted wages in the ML estimation. The probability of receiving a wage offer while unemployed and the layoff rate are almost identical in both estimations, around 0.93 and 0.046, respectively. However, the probability of receiving a wage offer while employed is substantially different in the two results: 0.16 by ML and 0.36 by SMM. A crucial aspect of the model is that it generates quits to unemployment when the difference in offer probabilities while unemployed and while employed is high. The lower λ_e estimated by ML implies a better replication of quits to unemployment than SMM. On the contrary, precisely because of its higher λ_e, SMM does better in replicating job-to-job transitions. The two wage functions are also dissimilar in these two estimations: the ML estimated wage offer distribution generates higher wages but less wage growth than SMM. Therefore, the income pattern implied by the SMM parameters generates less asset accumulation than the ML parameters. Except for λ_e and for λ_u in the ML estimation, which allow the model to account for quits to unemployment because of asset accumulation, similar labor market parameters where found by Wolpin (1992).

The coefficient of risk aversion is 1.48 for ML and 1.04 for SMM, which are both comparable to prior estimations. The estimated parameter s is 0.14 for ML and 0.04 for SMM, which reveals an environment of very tight borrowing constraints.

Measurement errors in the ML estimation errors are large, probably because of sizeable asset fluctuations in the data, which in turn have their origin precisely in large errors of measurement.[16] In particular, as quits to unemployment only happen at low asset levels, quits at higher observed asset levels increase the measurement error in assets and also in wages, which in the model are closely related to assets. Unfortunately, as discussed by Bound and Krueger (1991), large measurement errors are usual in applied research, especially in a longitudinal analysis, privileged by the ML estimation. By contrast, the measurement error in wages is substantially lower in the SMM estimation: whereas in the ML estimation the measurement error represents 39% of the total variation in wages, in the SMM estimation this fraction decreases to 27%, which is similar to what Wolpin (1992) finds in a structural framework. Asymptotic standard errors are calculated using the outer-product gradient estimator and provided in parentheses; they are in general small.

5.2 Accuracy of the Model

To assess whether these parameter estimates capture the essential features of the data, I compare the observed and the predicted choice distributions of employment status, employment transitions, assets, and wages.

[16] See Rust (1990) for a discussion on the severity of measurement errors in assets data from the Retirement History Survey (RHS).

Figure 3 presents the estimated initial asset distributions for all individuals, which coincide with previous descriptions of asset distributions of young agents, for instance by Budría et al. (2002) , in that they are significantly skewed to the right, reveal a high level of wealth concentration, and allow for an important proportion of negative assets. The implied lower bound of assets is -1,000 in the SMM estimation and -6,000 in the ML estimation. Since the SMM estimates produce tighter borrowing constraints, their asset distribution stochastically dominates over the ML distribution. With these initial conditions I simulate several career paths, as explained in Section 2, and compute hazard rates for the first unemployment spell and predicted moments by quarter after graduation.

Figure 4 shows the actual and the predicted hazard rates for the first unemployment spell, both decreasing over time. Notice that the unemployed run down their assets and reduce their reservation wages, so hazard rates must be increasing. However, with non-generate distribution of initial assets, poor individuals, those with high hazard rates, are the first to exit unemployment, so that predicted average hazard rates decline over time.

Table 7 provides a summary of actual and predicted distributions of all variables for years 3, 6, and 9 after graduation. It also shows goodness of fit tests[17] to evaluate whether the cell-by-cell distribution of the data can be produced by the theoretical model at the estimated parameters. In addition, Figure 5 presents a graphical comparison of actual and predicted variables by quarter after graduation. Figure 5a shows the unemployment rates. Both predicted paths are relatively close to the actual path; however, the ML path is higher at all times than the SMM path. More concretely, at the beginning of the employment careers the ML path is closer to the actual path and, accordingly, produces lower chi-square statistics, but SMM performs better in

[17] The simplest test statistic across choices j at time t is defined as $\chi_t^2 = \Sigma_{j=1}^{J} \frac{(n_{jt}-\hat{n}_{jt})^2}{\hat{n}_{jt}}$, where n_{jt} is the actual number of observations of choice j at time t, $\hat{n}_{jt}$ be the model predicted counterpart, J is the total number of possible choices and T is the number of years. This statistic has an asymptotic χ^2 distribution with $J-1$ degrees of freedom.

later years.

The predicted transitions between unemployment and employment, shown in Figures 5b and 5c, present a fairly good replication of the actual paths. ML shows lower transitions from unemployment to employment but higher transitions from employment to unemployment, which explains its higher predicted unemployment rate. The χ^2 statistics for the transitions from unemployment fall below the critical value at a 0.5% of significance in both estimations. However, as shown in Figure 5d, both estimations underpredict job-to-job transitions, though the SMM estimation, which has higher arrival rates while employed, is closer to the actual path. Altogether, the choice distributions of the transitions from employment do not pass the χ^2 test, although the χ^2 statistics go down over time.

The percentage of layoffs in the transitions from employment, to unemployment and job-to-job, is shown in Figures 5e and 5f, respectively. The ML parameters, in particular the lower arrival rate while employed, imply more quits to unemployment, and thereby a predicted path that is closer to the actual one and passes the chi-square tests. There is no big difference between these two predictions for layoffs in job-to-job transitions; both underpredict the actual path, though SMM performs better in terms of the chi-square tests.

Figures 5g and 5f show the evolution of assets and wages, respectively. Both predictions capture different aspects of these observed variables. The ML estimation, with looser borrowing constrains, higher wage offers, and a lower wage growth, captures better the trend to the observed asset accumulation, but it overpredicts wages, especially at the beginning of the employment careers. The χ^2 statistics for these variables go down over time, reflecting the convergence of predicted and actual distributions. The SMM estimation shows a close replication of observed assets at the beginning of the employment career, but it underpredicts assets in later periods. Accordingly, the chi-square falls below the critical value in early years, but it increases in later years. However, it shows a more accurate replication of observed wages over time; in particular, it produces a wage growth that is similar to the actual counterpart.

In short, both estimations show that the model is successful in replicating the main features of the data. While the strength of the ML estimation lies in its better reproduction of asset accumulation and quits to unemployment, SMM performs better in predicting the wage evolution and job-to-job transitions.

6 Policy Experiments

After recovering the underlying parameters of the model by the two estimation methods and assessing their success in replicating the data, I perform two regime changes and report them in Table 8. These experiments measure the variations in several observables produced by increasing initial assets and relaxing borrowing constraints. Both parameter estimates show basically the same effects, though their amounts are somewhat different.

The first experiment consists of displacing the initial asset distribution to the right by $5,000. Making agents wealthier by this amount increases the duration of the first unemployment spell, between 0.67 and 0.84 quarters, as well as the unemployment rate, between 14 and 21 percentage points. It also raises the first accepted wage by more than $400 and average wages in the first quarter by around $800. The increase in the unemployment rate and in wages is persistent and fairly notorious twenty quarters after graduation, especially with the ML parameters, but it dies out for the 40th quarter.

The increase in initial assets produces increases in assets and consumption in later periods: even forty quarters after graduation, when the increase in wages practically disappeared, the increase in wealth is still significant: between $150 and $490. This persistent increase in the level of wealth undermines the need for saving and, consequently, the saving rate declines. In the long run this regime change increases cumulative discounted utility.

The second experiment consists of relaxing borrowing constraints by setting them to half of the natural borrowing limit, that is, $s = 0.5$. Certainly, this change has stronger effects with the SMM parameter set, for it implies abandoning a regime with practically no access to credit. This change produces an increase in the duration of the first unemployment spell, between 0.8 and 0.94 quarters, and in the unemployment rate over time, between 13 and 23 percentage points. As individuals with more access to credit are more selective, they search longer for a job and end up with higher wages: the first accepted wage increases between \$430 and \$590. Similarly, accepted wages also show an important and persistent increase: between \$740 and \$930 in the first quarter, between \$50 and \$70 in the twentieth quarter, and between \$20 and \$40 in the fortieth quarter. Given that a relaxation of the borrowing constraints is a permanent change, it is not surprising that effects are more persistent than in the previous experiment.

Since less constrained agents can rely on debt for their job search and consumption, their need for building up a buffer stock is less stringent. In this experiment relaxing borrowing constraints means a decline in assets of between \$3,600 and \$8,000. Thus, at the beginning of their employment careers less constrained agents consume more than more constrained ones. However, as the wage gap between these two agents narrows down, less constrained agents have lower wealth, lower consumption, and a higher saving rate, particularly under the SMM parameters. As one would expected, relaxing borrowing constraints increases welfare.

7 Conclusions

This paper has shown that borrowing constraints are relatively tight: between 4 and 14% of the natural borrowing limit. Moreover, borrowing constraints reinforce the influence of wealth on individuals' job acceptance decisions. An increase of \$5,000 dollars in initial assets raises accepted quarterly wages by $800 in the first quarter after graduation and by lower amounts several periods afterwards. I also show that in this context relaxing borrowing constraints increases wages for several periods after graduation: if they were half of the natural limit, wages in the first quarter after graduation would raise by $900 and remain higher for several periods. To my knowledge, this is the first paper that numerically characterizes and estimates the joint job search and asset accumulation decisions under borrowing constraints.

The model proposed in this paper generalizes Danforth's (1979) model to allow for on-the-job search, wage growth, retirement, and a parametric borrowing limit. It accounts for features of the data such as asset decumulation to maintain consumption during unemployment and asset accumulation during employment, which responds to the need of agents to build a buffer-stock against future unemployment. In particular, this model generates quits to become voluntarily unemployed as an optimal decision motivated by the desire of the individual to search for better jobs while unemployed.

Using maximum likelihood and method of moments procedures, I fit this model to data from the NLSY, recover the behavioral parameters and the initial asset distribution, and compare the results. While the maximum likelihood estimation performs better in replicating asset accumulation and quits to unemployment, the method of moments estimation predicts better the wage evolution and job-to-job transitions. However, both procedures deliver in general a good replication of the hazard rate during the first unemployment spell and the cross-sectional distributions of assets, wages, and employment transitions over time.

These results are encouraging for further applied research based on utility-maximizing search models. Future work can easily use and extend this framework to study other issues in labor economics, for instance, job search and savings prior to retirement or the effect of unemployment transfers on savings.

Appendix

A1. Numerical Solution of the Model

As mentioned in the main body of the paper, the model is solved on a discretized state space. The table below gives further details of this discretization.[18]

Discretization of variables		
	Assets	Wages
Original variable	A	ω
Discretized variable	$A(i)$	$\omega(j)$
Gridpoints	$i = 1, ..., N_A$	$j = 1, ..., N_w$
Number of gridpoints	$N_A = 201$	$N_w = 51$
Lower Bound	$\underline{A} = -10,250$	$\underline{w} = 1,000$
Upper Bound[19]	$\overline{A} = 55,250$	$\overline{w} = 10,000$
Gridsize	$\Delta_A = \frac{\overline{A}-\underline{A}}{N_A}$	$\Delta_w = \frac{\ln \overline{w} - \ln \overline{w}}{N_w}$

The discrete probability for a wage draw $\omega(j)$ is

$$\widehat{f}(j) = \frac{\Phi\left(\frac{\ln \omega(j)+\Delta_w/2-\mu}{\sigma_w}\right) - \Phi\left(\frac{\ln \omega(j)-\Delta_w/2-\mu}{\sigma_w}\right)}{\Phi\left(\frac{\ln \overline{w}-\mu}{\sigma_w}\right) - \Phi\left(\frac{\ln \underline{w}-\mu}{\sigma_w}\right)}.$$

Wage as a function of tenure $w(\omega, k)$ is also discretized and becomes $w(j,k){=}\omega(j)\exp\left(\alpha_1 k + \alpha_2 k^2\right)$. The maximum attainable tenure level is $\overline{k} = 8$.

The numerical solution proceeds in the following steps

1. For $t = T+1$ define the discretized value functions:

$$\begin{aligned} \widehat{V}^u[i,t] &= V_R(A(i)), \text{ and} \\ \widehat{V}^e[i,j,k,t] &= V_R(A(i)), \end{aligned}$$

   where $V_R(A(i))$ is the discretized value of being retired. For a CRRA utility function, this value function admits an analytical expression:

$$V_t^R(A_t) = \max_{\{A\}_{s=t}^{T_F}} \sum_{s=t}^{T_F} \beta^{s-t} \frac{\left(A_s - \frac{A_{s+1}}{1+r}\right)^{\gamma} - 1}{1-\gamma} = \frac{A_t^{1-\gamma}}{1-\gamma} c_1^{\gamma} - \frac{1}{1-\gamma} c_2,$$

   where $c_1 = \frac{1-\left[\frac{g}{1+r}\right]^{T_F-T+1}}{1-\frac{g}{1+r}}$, $g = [\beta(1+r)]^{\frac{1}{\gamma}}$, $c_2 = \frac{1-\beta^{T_F-T+1}}{1-\beta}$, and $A_{T_F+1} = 0$.

   Analytical solutions for consumption and for assets are $C_t = \frac{g^{t-T}}{c_1} A_T$ and

[18] The computation of the DP and the likelihood function is sensitive to the discretization of the state variables, especially of assets. Few gridpoints for assets reduce the accuracy of the model in replicating observed quits and savings, and estimating the borrowing limit. The choice of 201 gridpoints for assets, almost four times as much as the number of gridpoints for wages, aims to ameliorate this problem.

[19] Fewer than 9% of asset and fewer 3% of wage observations lie outside the admissible range defined by these bounds.

$A_t = \frac{g^{t-T}}{c_1} A_T \left(\frac{1-\left(\frac{g}{1+r}\right)^{T_F - t+1}}{1-\frac{g}{1+r}} \right)$, respectively. With $\beta(1+r) < 1$, consumption and assets of the retired decrease monotonically over time. Individuals are assumed to live for 20 years (80 quarters) after retirement.

2. Integration. Define the discretized expected values

$$
\begin{aligned}
W^u[i,t] &= \lambda^u \sum_{j=1}^{N_w} \max\left[\widehat{V}^e[i,j,0,t], \widehat{V}^u[i,t]\right] f(j) + (1-\lambda^u)\widehat{V}^u[i,t]; \\
W^e[i,j,k,t] &= (1-\theta)\left(\lambda^e \sum_{l=1}^{N_w} \max\left[\widehat{V}^e[i,j,k,t], \widehat{V}^e[i,l,0,t], \widehat{V}^u[i,t]\right] f(l)\right. \\
&\quad \left. + (1-\lambda^e)\max\left[\widehat{V}^e[i,j,k,t], \widehat{V}^u[i,t]\right]\right) \\
&\quad + \theta\left(\lambda^e \sum_{l=1}^{N_w} \max\left[\widehat{V}^e[i,l,0,t], \widehat{V}^u[i,t]\right] f(l) + (1-\lambda^e)\widehat{V}^u[i,t]\right).
\end{aligned}
$$

3. Compute the value function for the previous period

$$
\begin{aligned}
\widehat{V}^e[i,j,k,t] &= \max_{q \geq i^*(t+1)} \left\{ U\left(A(i) + w(j,k) - \frac{A(q)}{1+r}\right) + \beta W^e\left[q,j,k',t+1\right] \right\}, \\
\widehat{V}^u[i,t] &= \max_{m \geq i^*(t+1)} \left\{ U\left(A(i) + b - \frac{A(m)}{1+r}\right) + \beta W^u[m,t+1] \right\},
\end{aligned}
$$

where $A(i^*(t+1)) = B_{t+1}$. The maximizers to these problems are $q^* = q^*(i,j,t)$ and $m^* = m^*(i,t)$; the reservation wage is $j^*(i,k,t) = \left\{ j \,\middle|\, \widehat{V}^e[i,j,k,t] \geq \widehat{V}^u[i,t] > \widehat{V}^e[i,j-1,t] \right\}$.

4. Go to step 2. This process goes backwards and it is repeated until reaching period $t = 1$.

This procedure, applied for the simulation of Section 2, is not applied for the estimation, because it is too time-consuming. The entire working lifetime T is assumed to be 162 quarters. As in Wolpin (1992), the estimation is made tractable assuming that the individual solves the DP problem using longer period lengths for the more distant future value functions. Let n be the period length measured in quarters. From quarter 162 through quarter 83 the individual acts as if optimization occurs over two year periods ($n = 8$), from quarter 82 through quarter 51 over one year periods ($n = 4$), and from quarter 50 through quarter one over quarterly periods ($n = 1$). This is illustrated by the following scheme:

	50 quarterly periods	8 annual periods	10 biannual periods
Quarters:	1, 2, 3,......, 49, 50	51, 52, 53,......, 81, 82	83, 84,......, 161, 162

The DP problem has to be converted to match these varying period lengths. The arrival and discount rates are adjusted to the corresponding period length, $n = \{1, 4, 8\}$:

$$\lambda_n^u = 1 - (1-\lambda^u)^n; \quad \lambda_n^e = 1 - (1-\lambda^e)^n; \quad \theta_n = 1 - (1-\theta)^n; \quad \beta_n = \beta^n.$$

For annual and biannual period lengths, the quarterly consumption is assumed to be constant. If the agent is unemployed and consumes C_u in each quarter, assets at the end of a period of length n are

$$A_n = (1+r)^n A + b \sum_{j=1}^{n} (1+r)^j - C_u \sum_{j=1}^{n} (1+r)^j .$$

The utility function for a period of length n from quarterly consumption C_u is then

$$\begin{aligned} U_n (C_u) &= \sum_{t=0}^{n} \beta^t U (C_u) = \frac{1-\beta^n}{1-\beta} U (C_u) = \frac{1-\beta^n}{1-\beta} U \left(g_n A_n + b - g_n \frac{A_n}{(1+r)^n} \right) \\ \text{where} &: \; g_n = \frac{(1+r)^n}{\sum_{j=1}^{n} (1+r)^j} = \frac{1 - \frac{1}{(1+r)}}{1 - \frac{1}{(1+r)^{n+1}}}. \end{aligned}$$

Consumption is also constant when the individual is employed, without any change in the wage offer distribution, but with an adjustment for wage growth. I assume that in annual and biannual periods quarterly consumption is determined by the average level of work experience inside those periods, that is, by half of the employment duration. Let k_n be the experience accumulated in one period of length n; then quarterly experience is $k = \frac{k_n n}{2}$, and the maximum attainable tenure is $\overline{k}_n = \frac{\overline{k}}{n}$ (The choice of $\overline{k} = 8$, facilitates this adjustment, as $n = \{1, 4, 8\}$). The quarterly wage for a person with tenure of k_n periods of length n is thus

$$w_n (\omega, k_n) = \omega \exp \left(\alpha_1 k + \alpha_2 k^2 \right) = \omega \exp \left(\alpha_{1n} k_n + \alpha_{2n} k_n^2 \right)$$

where $\alpha_{1n} = \alpha_1 n/2$ and $\alpha_{2n} = \alpha_2 n^2/4$. Hence, the utility function for a period of length n from a constant quarterly consumption C_e of an employed agent with initial wage ω and tenure k_n is

$$U_n (C_e) = \sum_{t=0}^{n} \beta^t U (C_e) = \frac{1-\beta^n}{1-\beta} U \left(g_n A_n + w_n (\omega, k_n) - g_n \frac{A_n}{(1+r)^n} \right)$$

This way, the DP problem is solved by choosing assets next period regardless of the period length, just by making the necessary adjustments in the utility function and its arguments during the backwards solution.

A2. Definition of the variables

For tractability, the data have been aggregated to quarters based on the calendar quarter in which the individual starts his employment history. The last week that the individual reports having being enrolled in school is assigned to its corresponding calendar quarter; employment history is defined to start in the quarter thereafter. The relevant time unit is quarters after graduation, not calendar time. Along with attrition and missing data, this implies that not all people are observed through 1993. The unavoidable consequence of the aggregation to quarterly data is some definitional arbitrariness. An individual is considered to be working if he is employed during the first week of the quarter; otherwise he is considered as "unemployed" for that quarter. The job corresponding to that quarter is also the first job of the quarter; any other job held during the quarter is ignored (Unfortunately, any construction of quarterly data implies missing transitions when there is a high turnover.). The quarterly wage related to that job is the wage of the first week of the quarter in 1985 dollars times 13. Since the NLSY provides information on multiple jobs held at the same period by a person, the main job is taken to be the one with the most hours of work. A person is given the status of employed if he works 20 or more hours per week. The Consumer Price Index is used to transform the monetary values into real amounts.

The survey has data for the reason for leaving a given employer, which are classified into voluntary or involuntary reasons. It is considered a layoff when the respondent reports having been laid off, fired or discharged, that the program ended or that the plant closed. Other reasons such as family reasons, spouse changing jobs, finding a better job, quits to look for another jobs and other reasons are classed as quits. Since the model does not incorporate temporary layoffs, individuals returning to work for their old employers are considered as having taken new jobs.

The NLSY contains annual data on the financial characteristics of the household, which are only available for years 1985 until 1993, with exception of year 1991. Respondents report the market value of their assets at the moment of the interview; this information is therefore assigned to its particular calendar quarter, leaving blank all other quarters. There are five types of assets: residential property, financial assets, business assets, vehicles and other; all these components are computed at their "market value" which the NLSY defines as the amount the respondent would reasonably expect someone else to pay if the particular asset were sold today in its present condition. Because the model does not incorporate explicitly the existence of heterogeneous assets, they are treated as equally liquid.[20] This definition corresponds to the notion of wealth as a store of value used in the standard national accounting framework (Wolff 1990). Accordingly, the net value reported for total assets is the sum of the components. If the respondent does not report at least one of them, the assets variable is reported as not available.

The five components of assets are defined as follows.

1. Residential property refers to the net value of the respondent's house or apartment owned or being bought by the individual. That is the market value of the property, net of liabilities such as mortgages, back taxes, home improvement loans, or debts such as assessments, unpaid amounts of home improvement loans, or home repair bills.

2. Financial assets contain money in saving or checking accounts, saving and loan companies, money market funds, credit unions, US saving bonds, individual retirement accounts (IRA or KEOGH), or certificates of deposit, common stock, stock options, bonds, mutual funds, rights to an estate or investment trust, or personal loans to others or mortgages held by respondent. This concept also includes money owed to the respondent by other people.

3. Business assets refer to the net market value of a farm, business or other property. Examples of this category are investment in a farm operation, a business or professional practice, or any other real estate, including tools and equipment, livestock, and stored crops. Debts or liabilities owned on this operation or property are subtracted; unpaid mortgages are included; commodity credit loans are excluded.

4. 'Vehicles' include the market value of vehicles, including cars, motorcycles, trucks, a motor home or trailer, net of debts.

[20] Admittedly, an important reason for saving is the down payment of home purchasing (Engelhardt 1994). However, studying the interaction between buying a house and employment decisions is beyond the goal of this paper and is left for future research.

5. Other assets refer to the difference of the value of other assets worth more than \$500 minus the amount of other debts over \$500. Examples of these assets are a piece of furniture, an appliance, stereo, a boat, a piece of jewelry, a valuable collection for investment purposes, etc. Examples of debts are those owed to any stores, doctors, hospitals, banks, or anyone else, excluding 30-day charge accounts.

A3. Likelihood function

To construct the likelihood function, I exploit the discretization of the continuous variables to solve the DP problem, explained in Appendix A1, and compute the likelihood as a Markov chain. The multiple integrations required to construct this function become summations which are computed recursively. Similarly, the densities of the measurement errors described in Section 4 become discrete probabilities, defined as

$$\begin{aligned} h_A(i_A) &= \Phi\left(\frac{\epsilon_A(i_A)+\Delta_A/2}{\sigma_A}\right)-\Phi\left(\frac{\epsilon_A(i_A)-\Delta_A/2}{\sigma_A}\right), \text{ and} \\ h_w(i_\omega) &= \Phi\left(\frac{\epsilon_w(i_\omega)+\Delta_w/2}{\sigma_w}\right)-\Phi\left(\frac{\epsilon_\omega(i_\omega)-\Delta_w/2}{\sigma_w}\right), \end{aligned}$$

where i_A indexes the discretized version of ϵ_A and i_w indexes ϵ_ω.

Define $\Lambda(i,j)^t$ as the joint probability of reaching assets $A(i)$ and wages net of work experience $\omega(j)$, at time t and observing the past sequence of assets and wages up to this point:

$$\Lambda(i,j)^t = \Pr(A(i),\omega(j),\left\{i_l^{obs},j_l^{obs}\right\}_{l=t_0+1}^{t}|i_{t_0}^{obs},j_{t_0}^{obs}).$$

When an individual is employed, $j\geq 1$; when the individual is unemployed $j=0$. Given that employment status and layoffs are not observed with error, this array can account for all possible true values of assets, employment status and wages. At period t_0 the joint probability that an individual has assets of $A(i)$ and net wages of $\omega(j)$, conditional on observed assets and wages is

$$\Lambda_{t_0}(i,j) = h_A\left(i_1-i_1^{obs}\right)\times h_w\left(j_1-j_1^{obs}\right).$$

From this first observation, $\Lambda(i,j)^t$ is computed iteratively using the expression

$$\Lambda_{t+1}(i',j') = \sum_i\sum_j \Lambda_t(i,j)\times\widehat{g}(i',j'|i,j,t)\times h_A\left(i'\left(i,j\right)-i_1^{obs}\right)\times h_w\left(j'-j_1^{obs}\right),$$

where $\widehat{g}(i',j'|i,j,t)$ is a discretized version of the five transition probabilities shown in the main text.

$\Lambda(i',j')^{t+1}$ is defined analogously to $\Lambda(i,j)^t$ as the joint probability of reaching assets $A'(i')$, and wages $\omega(j')$, and observing the past sequence of assets and wages at time $t+1$. For each value of the unobservables $A(i)$ and $\omega(j)$, we have to compute the probability of moving to assets $A'(i')$, and net wages $\omega'(j')$.

The likelihood contribution for an individual is computed by integrating $\Lambda(i,j)^T$ over all possible values of the unobservables $A(i)$, and $\omega(j)$, i.e.

$$\mathcal{L} = \Pr\left(\left\{i_l^{obs},j_l^{obs}\right\}_{l=2}^{t}|i_1^{obs},j_1^{obs}\right) = \sum_i\sum_j \Lambda_T(i,j).$$

Notice that the unobservable true values only intervene in these expressions to facilitate the recursive computation of multiple integrals. At the end of the iteration, the likelihood function is the probability of observing the data given certain parameter values.

A4. Simulated Method of Moments

The discrete distribution of an observed variable is characterized by a set of J frequencies p_j, $j = \{1, .., J\}$. Let n be the total number of observations of the actual variable and n_j the number of observations of the actual variable in the jth cell. The predicted counterparts of the frequencies and the number of observations for the jth cell are $\widehat{p}_j$ and $\hat{n}_j$, respectively. Let $\Delta p' = [\Delta p_1, \cdots, \Delta p_J]'$ be a vector in which $\Delta p_j = p_j - \widehat{p}_j$, that is, the difference between the actual and the predicted percentage for each cell. A method of moments estimation minimizes the weighted average distance between the actual and predicted distributions $\Delta p' W^{-1} \Delta p$, where W is a diagonal matrix in which each element of the main diagonal is $\frac{\widehat{p}_j}{n}$. Then, the weighted average distance of a variable, indexed now by k, becomes

$$\Delta p' W^{-1} \Delta p = \sum_{j=1}^{J} \Delta p_j^2 \left(\frac{\widehat{p}_j}{n} \right)^{-1} = \sum_{j=1}^{J} \frac{(p_j - \widehat{p}_j)^2 n^2}{\widehat{p}_j n} = \sum_{j=1}^{J} \frac{(n_j - \hat{n}_j)^2}{\hat{n}_j} = \chi_k^2.$$

Since a sum of chi-square random variables follows also a chi-square distribution, with this diagonal weighting matrix the weighted average distance for K variables is $\chi^2 = \sum_{k=1}^{K} \chi_k^2$. Hence, matching the simulated moments to the moments observed in the actual dataset is equivalent to computing a χ^2-statistic for the selected distributions.

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Table 1: Assets, Unemployment and Wages by Years after Graduation.
White Male High School Graduates between 1978 and 1993

Variable	Year 3	Year 6	Year 9
Average Assets	6,023	9,278	13,329
% of people with:			
Assets ≤ 0	6.25	12.32	10.00
$0 <$ Assets$\leq 10,000$	75.00	57.25	47.14
$10,000 <$ Assets$\leq 20,000$	9.38	18.12	17.14
$20,000 <$Assets$\leq 30,000$	6.25	3.62	10.71
Assets $> 30,000$	3.13	8.70	15.00
% Unemployed	18.34	10.94	8.83
Average Quarterly Wage	3363	4114	4552

Note: the amounts are given in dollars of 1985. An individual is considered unemployed if he works less than 20 hours in a week. Source: NLSY.

Table 2: Average Quarterly Savings according to Employment Transitions

Employment Status t	$t+\Delta$ Un-employment	$t+\Delta$ Same Employment	$t+\Delta$ New Employment	Total
Unemployment	-1,597	0	1,005	123
	(41)		(80)	(121)
Employment	-6095	1542	332	773
	(67)	(685)	(151)	(903)
Total	-4387	1542	565	696
	(108)	(685)	(231)	(1024)

Note: The number above is saving, defined as the average quarterly variation of assets between periods when asset holdings are observed. The first number below is the number of people involved in the transition. The employment status in the first period, t, is described in the first column. The employment status. in the next period when assets are observed, $t+\Delta$, is reported in the first row. Source: NLSY

Table 3: Sensitivity Analysis: Statistics for Baseline Parameters and for variations of one parameter at a time

Levels		Variation in statistics from of a change in one parameter at a time								
	Parameter	b	λ_u	λ_e	θ	μ	σ	α_1, α_2	γ	s
	Baseline	400	0.90	0.20	0.04	6.5	0.90	0, 0	1.2	0.1
	Variation	100	0.05	0.05	0.01	0.2	0.10	0.01, -0.001	0.3	0.4
Period										
Unemployment rate										
1	68.63	2.36	-1.60	-3.16	-3.16	-1.32	-2.17	0	-3.16	7.12
20	11.37	0.56	0.47	-1.61	1.79	0.28	0.38	0	-1.04	0.23
40	12.22	1.32	-0.19	-1.61	1.80	0.33	1.13	0.23	-0.14	1.36
Wages										
1	3211	97	18	-118	-118	237	319	0	-118	325
20	3647	61	49	11	-43	333	517	52	-79	97
40	3946	64	40	32	-108	362	576	59	-44	71
Assets										
20	4006	-681	51	-411	546	688	1283	139	869	-6361
40	8148	-741	70	-420	506	1117	2074	96	1946	-6338
Consumption										
1	1796	85	33	74	-6	83	97	23	-7	837
20	3124	43	23	58	-104	263	412	46	-82	22
40	3403	6	35	69	-146	298	471	51	-43	-118
Saving Rates										
1	-40.11	-2.96	2.85	-0.54	5.48	5.53	9.54	-1.80	5.56	-86.78
20	4.70	0.07	0.10	0.03	0.40	0.23	0.30	-0.07	1.43	1.56
40	3.13	0.44	0.15	0.38	-0.16	-0.08	-0.66	-0.26	0.29	03.7
Welfare										
40	107.45	0.13	0.06	0.16	-0.18	0.40	0.55	0.06		0.66
% of Quits in transition from Employment to Unemployment										
20	27.96	-6.12	1.39	-6.01	-10.91	-5.61	-5.72	-3.54	-8.68	1.94

Table 4: Summary Statistics

Variable	
Average duration of first unemployment spell (quarters)	2.52
% of unemployed becoming employed	41.92
% of employed becoming unemployed	6.31
% thereof quit	32.32
% thereof are laid off	45.46
% of employed changing employer	8.53
% thereof quit	61.85
% thereof are laid off	26.29
Average wage growth (%)	
per quarter	2.20
when changing employer	14.52
Average asset growth (%)	
per quarter	3.25

Table 5: Composition of Net Assets according to Asset level and Years after Graduation

	Years ≤ 6 Asset Bracket in Thousands				Years > 6 Asset Bracket in Thousands			
	0-10	10-20	20-30	+30	0-10	10-20	20-30	+30
Residential	6.99	17.44	23.51	22.53	15.98	31.08	31.92	25.96
Financial	23.79	18.82	15.09	19.04	21.85	19.43	21.21	38.56
Business	5.13	5.30	13.78	42.32	5.40	3.37	4.13	22.35
Vehicles	50.11	33.02	33.07	6.18	52.51	28.53	26.17	7.03
Other	13.96	25.40	14.54	9.92	4.24	17.57	16.56	6.10

Table 6: Parameter Estimates
and Asymptotic Standard Errors (in parentheses)

Θ	ML	SMM
b	656.87	415.02
	(39.01)	(5.01)
λ_u	0.938092	0.932142
	(0.051156)	(0.007128)
λ_e	0.158281	0.362222
	(0.021573)	(0.009173)
θ	0.046283	0.046469
	(0.009304)	(0.001229)
μ	6.877250	6.369983
	(0.085290)	(0.005901)
σ	0.894435	1.000026
	(0.094311)	(0.001526)
α_1	0.002969	0.019497
	(0.000755)	(0.000096)
α_2	-0.000622	-0.003284
	(0.000014)	(0.000002)
γ	1.483435	1.042593
	(0.093012)	(0.008832)
s	0.135897	0.035255
	(0.012541)	(0.005781)
r	0.015	
β	0.98	
σ_A	19818.69	13000
	(812.12)	
σ_w	0.578638	0.382293
	(0.011378)	(0.000711)
$-ln\mathcal{L}$ / χ^2	5632.20	3398.93

Table 7: Summary. Actual and Predicted Choice Distribution (%): All Variables for three selected Years after Graduation

	Years after Graduation								
		Year 3			Year 6			Year 9	
	Act.	ML	SMM	Act.	ML	SMM	Act.	ML	SMM
Employment Status									
Unemployment	18.34	15.86	9.23	10.94	14.53	8.54	8.83	15.83	9.54
Employment	81.66	84.14	89.06	89.06	85.47	91.46	91.17	84.17	90.46
χ^2		3.90	83.67		8.64	6.14		29.53	0.47
Transitions from Unemployment									
to Unemployment	62.58	61.49	51.47	54.95	67.37	53.59	52.11	67.37	57.23
to Employment	37.42	38.51	48.53	45.05	32.63	46.41	47.89	32.63	32.28
χ^2		0.07	3.86		8.49	0.05		24.91	0.82
Transitions from Employment									
to Unemployment	8.41	6.08	4.26	6.48	5.24	4.15	5.59	5.31	4.41
to same Employer	80.29	91.63	89.39	85.02	92.84	90.70	89.22	92.63	91.08
to a new Employer	11.30	2.28	6.35	8.50	1.92	5.14	5.18	2.06	4.51
χ^2		317.22	70.62		194.83	30.86		39.07	3.41
Transitions from Employment to unemployment									
Layoffs	69.39	64.75	83.23	56.76	76.05	87.27	62.07	82.85	88.76
Quits	30.61	35.25	16.77	43.24	23.95	12.73	37.93	17.15	11.24
χ^2		0.46	6.73		7.56	31.00		8.81	20.70
to a new employment									
Layoffs	34.33	7.36	9.41	20.00	5.76	11.53	33.33	12.93	14.74
Quits	65.67	92.64	90.59	80.00	94.24	88.47	66.67	87.07	85.26
χ^2		71.44	48.83		20.57	3.87		12.21	9.08
Assets									
Average	6023	2335	6004	9278	6112	6938	13329	9370	8430
Distribution									
$A \leq 0$	6.25	55.53	18.92	12.32	33.86	11.51	10.00	25.44	8.84
$0 < A \leq 10,000$	75.00	29.46	58.20	57.25	40.83	63.70	47.14	39.56	61.20
$10,000 < A \leq 20,000$	9.38	8.89	14.61	18.12	14.15	16.24	17.14	17.49	18.34
$20,000 < A \leq 30,000$	6.25	4.41	6.65	3.62	6.51	6.07	10.71	8.48	6.51
$A > 30,000$	3.13	1.71	1.63	8.70	4.66	2.48	15.00	9.03	5.11
χ^2		74.31	10.63		36.15	24.20		21.50	35.48
Wages									
Average	3363	4111	3746	4114	4384	4100	4552	4535	4279
Distribution									
$w \leq 2,000$	16.72	0.88	9.48	8.45	0.44	6.43	4.64	0.21	5.14
$2,000 < w \leq 4,000$	58.19	60.03	56.46	50.69	52.46	50.55	38.17	47.48	46.40
$4,000 < w \leq 6,000$	18.56	26.04	22.39	27.65	31.07	27.67	40.72	35.32	31.64
$w > 6,000$	6.52	13.05	11.67	13.21	16.03	15.34	16.47	16.99	16.83
χ^2		1731.86	50.83		951.42	6.04		641.80	27.51

Crit. values at .5% signif.: $\chi^2_{(1)} = 7.88$, $\chi^2_{(2)} = 10.60$, $\chi^2_{(3)} = 12.84$, $\chi^2_{(4)} = 14.86$.

Table 8: Summary of Two Policy Experiments

	Baseline Levels for both estimations		Variations			
			Displace $p(A_0)$ by 5000		Relax s to 0.5	
Quarter	ML	SMM	ML	SMM	ML	SMM
First Unemployment Spell						
Duration of unemployment						
	2.74	2.22	0.84	0.67	0.80	0.94
First accepted wage						
	3450	2839	449	438	436	590
Unemployment Rate						
1	62.41	48.02	13.67	20.90	13.06	23.35
20	15.09	9.91	0.24	-0.15	0	0. 51
40	15.80	9.76	0.05	0	0.76	0.33
Wages						
1	3477	2722	788	806	743	931
20	4355	4080	43	11	52	68
40	4609	4366	12	4	39	21
Assets						
1	1470	8933	4596	4311	0	0
20	5418	6710	998	507	-3589	-7616
40	11014	9219	489	149	-3599	-7994
Consumption						
1	2290	2757	785	735	646	1088
20	3606	3740	98	58	24	14
40	3803	3942	44	14	-55	-158
Saving Rate						
40	4.55	0.97	-0.90	-0.29	1.44	4.10
Welfare						
40	54.98	185.08	0.05	1.31	0.05	2.22

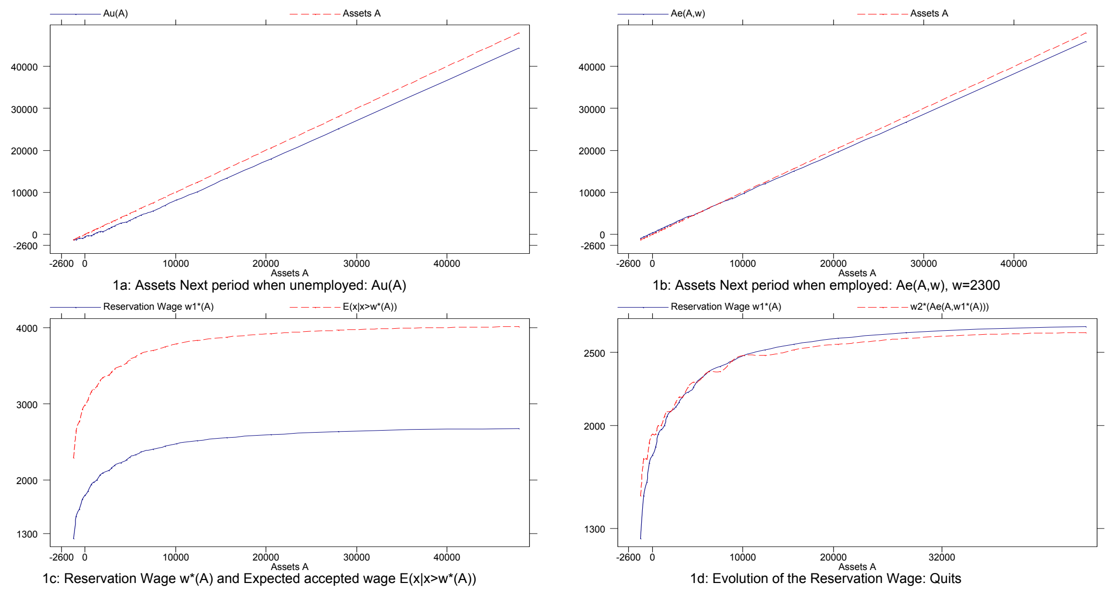

Figure 1: Policy Rules at t=1: Assets when Unemployed, Assets when Employed, Reservation Wages and Assets when Employed at the Reservation Wage

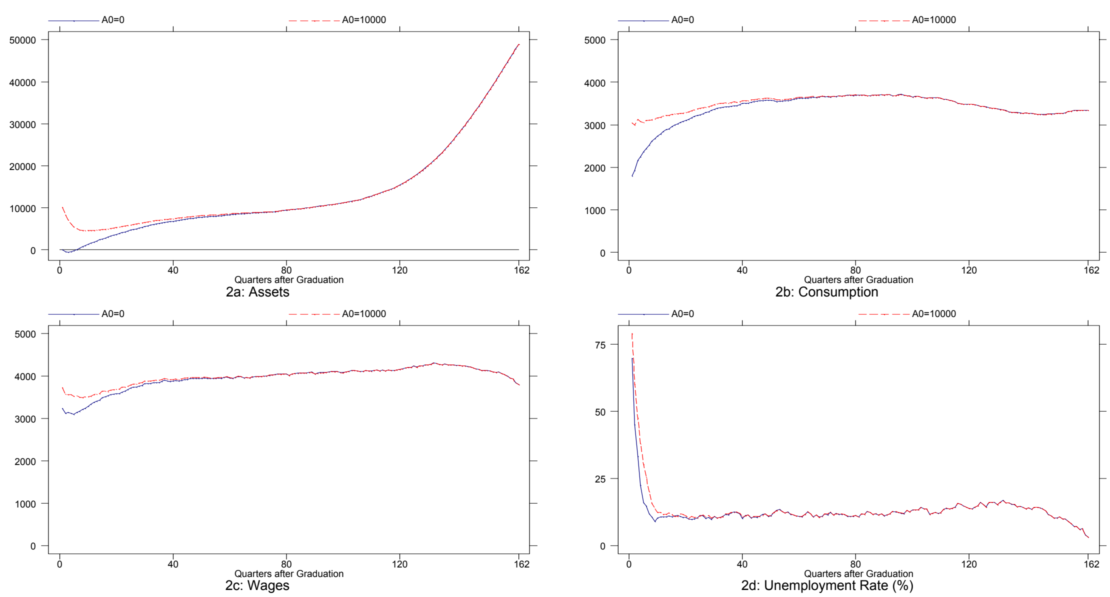

Figure 2: Quarterly Evolution of Assets, Consumption, Wages, and Unemployment Rate by Initial Assets

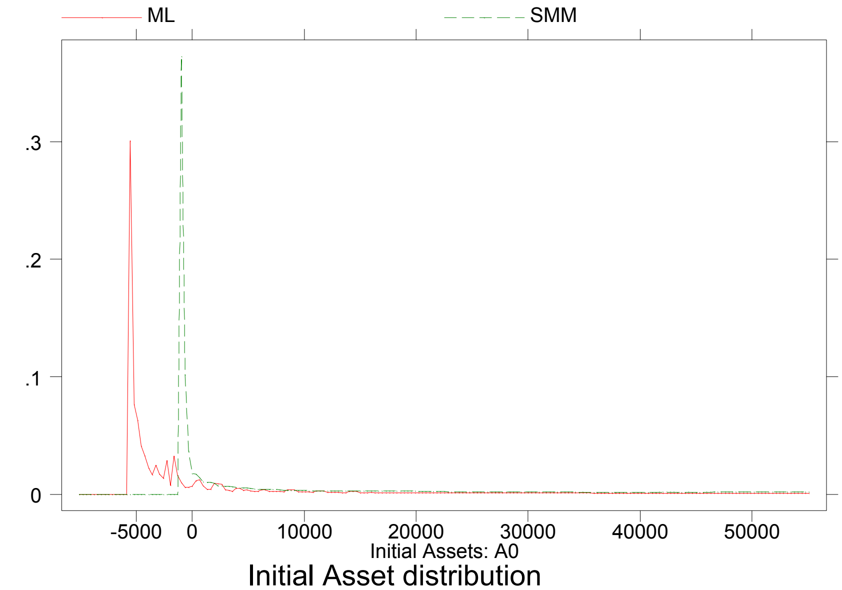

Figure 3: Recovered Initial Asset Distribution: $p\left(A_0|\Theta\right)$

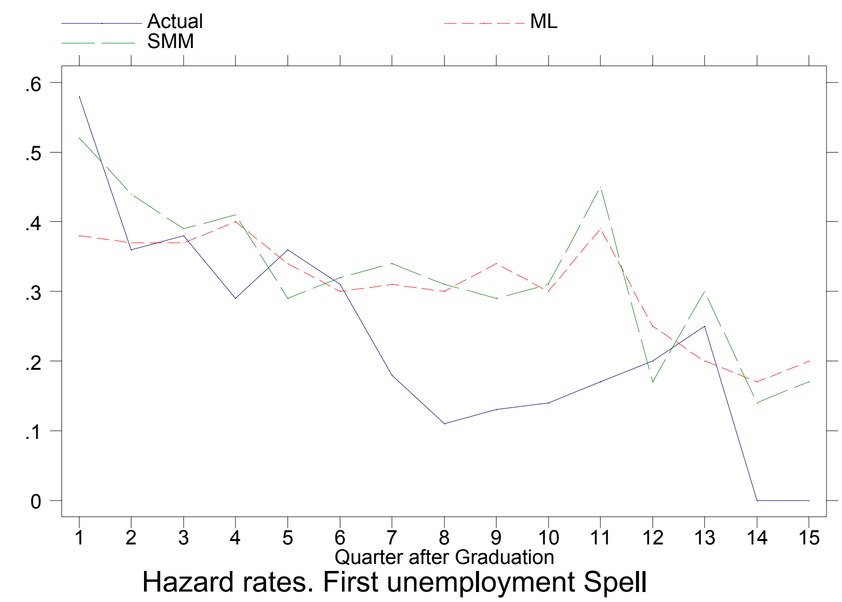

Figure 4: Actual and Predicted Hazard Rates

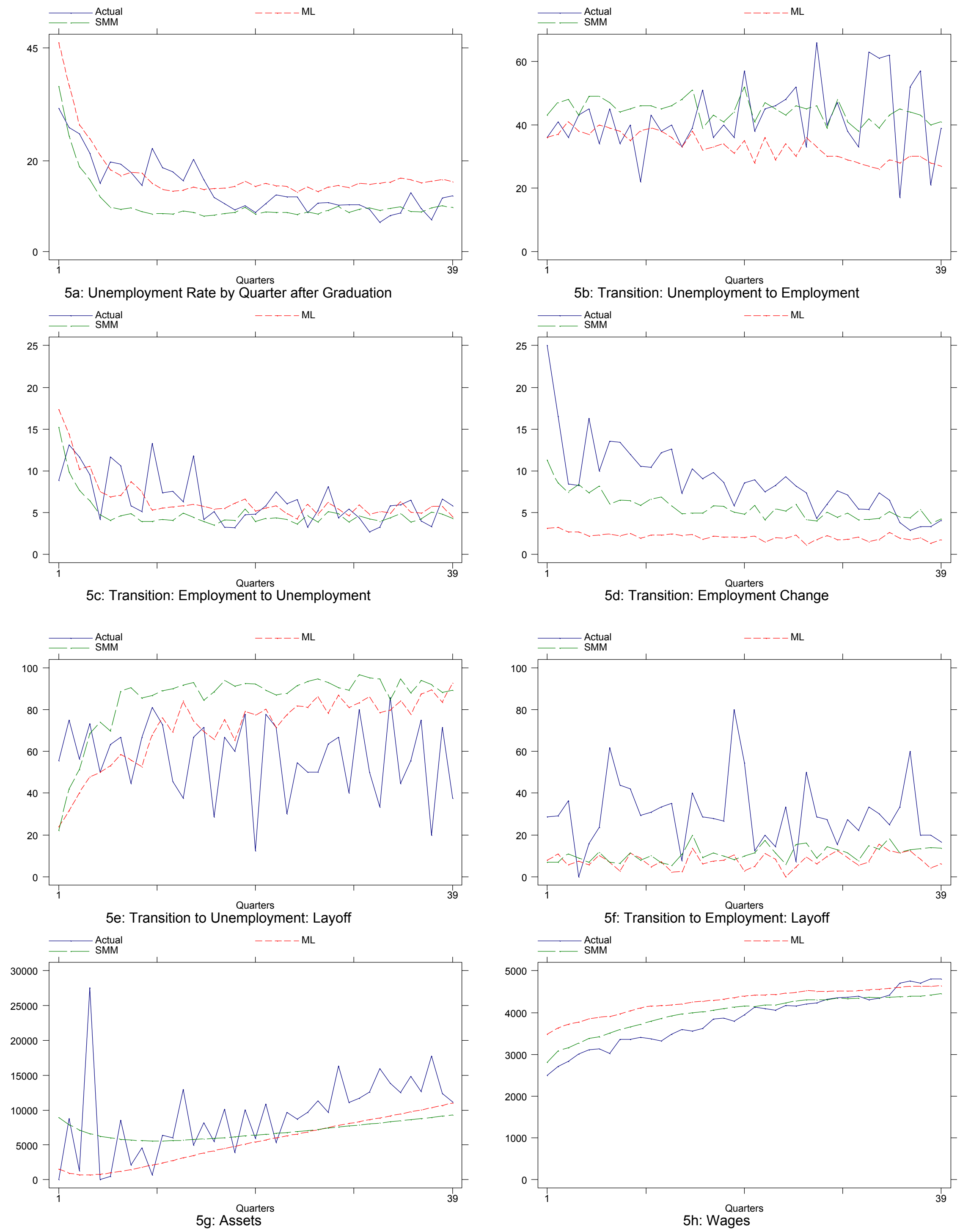

Figure 5: Actual and Predicted Variables by Quarter after Graduation