Web Appendix - Not for Publication

Reference-Dependent Job Search: Evidence from Hungary

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1 Reference Dependent Model

1.1 General Setup

Each period a job seeker decides search effort $s_t \in [0, 1]$, representing the probability of receiving a job offer at the end of period t and thus of being employed in period $t + 1$. Search costs are given by the function $c(s_t)$, which we assume to be time-separable, twice continuously differentiable, increasing, and convex, with $c(0) = 0$ and $c'(0) = 0$.

In each period individuals receive income y_t, either UI benefits b_t or wage w_t, and consume c_t. In the general model consumers smooth consumption over time by accumulating (or running down) assets A_t. Assets earn a return R per period so that consumers face a per-period budget constraint $\frac{A_{t+1}}{1+R} = A_t + y_t - c_t$ and a borrowing constraint $A_t \geq -L$. We also consider a simplified model with hand-to-mouth consumption, $c_t = y_t$.

1.1.1 Consumption Utility

Flow utility is a function of current period consumption and the reference point:

$$u(c_t|r_t) = \begin{array}{ll} v(c_t) + \eta [v(c_t) - v(r_t)] & \text{if} \quad c_t \geq r_t \\ v(c_t) + \eta\lambda [v(c_t) - v(r_t)] & \text{if} \quad c_t < r_t \end{array} \tag{1}$$

In the standard model, where $\eta = 0$, this simply collapses to:

$$u(c_t|r_t) = v(c_t)$$

1.1.2 Reference Point

The reference point is the average of income over the N previous periods:[1]

$$r_t = \frac{1}{N+1} \sum_{k=t-N}^{t} y_k \tag{2}$$

Note that the reference point is only a function of past income and therefore while in unemployment it is fully determined by the current period t. For an employed individual, the reference point will depend on the current period, as well as in which period the person started the post-unemployment job.

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[1]This formula implies that if $N = 0$, then $r_t = b_t$. In the hand-to-mouth case, where $c_t = y_t$, the reference-dependent utility then simplifies to the direct-consumption utility, $u(c_t|r_t) = v(c_t)$ and therefore the standard model is embedded. For the model with optimal consumption, even setting $N = 0$ the standard model is not any more embedded. In the estimation below we also consider an alternative AR(1) reference point formation process.

1.2 Model under exponential discounting

1.2.1 Value Functions

The unemployed choose search effort s_t and the asset level for the next period A_{t+1}, which implicitly defines consumption c_t, in each period. The state variables that determine the value of employment and unemployment in period t consist of the asset level A_t at the beginning of the period and the income levels of that individual over the last N periods: $\{y_t, y_{t-1}, y_{t-2}, \ldots, y_{t-N}\}$ since these past income levels determine the future evolution of the reference point via equation (2). One could thus write the value of unemployment as: $V_t^U(A_t, \{y_t, y_{t-1}, y_{t-2}, \ldots, y_{t-N}\})$. To save notation, we will not make this explicit and instead write $V_t^U(A_t) \equiv V_t^U(A_t, \{y_t, y_{t-1}, y_{t-2}, \ldots, y_{t-N}\})$, which is without loss of generality, since conditional on being unemployed the past income path is deterministically determined by the current period t. For an employed individual the income path over the past N periods depends on the current period t but also on when the individual found a job. We therefore use the notation: $V_{t|j}^E(A_t) \equiv V_t^E(A_t, \{y_t, y_{t-1}, y_{t-2}, \ldots, y_{t-N}\})$ for the value of employment for an individual in period t who started a job in period j. Note that a job that starts in period j is found in the prior period $j-1$.

The value of employment is given as:

$$V_t^U(A_t) = \max_{s_t \in [0,1]; A_{t+1}} u\left(c_t | r_t\right) - c\left(s_t\right) + \delta \left[s_t V_{t+1|t+1}^E \left(A_{t+1}\right) + \left(1 - s_t\right) V_{t+1}^U \left(A_{t+1}\right) \right] \qquad (3)$$

The value of employment in period t for an individual who starts a job in period j is given by:

$$V_{t|j}^E\left(A_t\right) = \max_{A_{t+1}>0} u\left(c_t | r_t\right) + \delta V_{t+1|j}^E\left(A_{t+1}\right). \qquad (4)$$

In both cases maximization is subject to the budget constraint: $c_t = A_t + y_t - \frac{A_{t+1}}{1+R}$ and the liquidity constraint: $A_t \geq -L$ for all t.

1.2.2 Solving the Model

There are 3 steps for solving the model:

1. For each period $j = 1, 2, \ldots$ find the value of employment $V_{j|j}^E(A_j)$ for an individual who starts a job in period j. This value will be a function of the asset level in period j: A_j. To do so, we first solve for the steady state value of employment which occurs when the environment becomes stationary at some point $j + M$ after taking on a job. From this steady state function we can solve the optimal consumption path between j and $j + M$ and infer from that the value of employment when accepting a job $V_{j|j}^E(A_j)$ for each asset level.

2. Once the value function of accepting a job at a given asset level is known, we can solve for the steady state value of unemployment at some point in the future S when the environment is stationary and then solve backwards for the optimal search intensity and consumption path in each period as a function of the asset level.

3. Finally, once we know the value of unemployment as a function of the asset level in each period, we use the initial asset level as a starting value to determine the actual consumption path and actual search intensity in each period.

1.2.3 Calculating value of accepting a job in each period

Stationary environment in employment: We assume that M periods after an individual takes on a job the environment for an employed individual becomes stationary. We require that an individual pays back their assets at this point so that we have that $r_t = c_t = w$ and $A_t = A_{t+1} = 0$.[2] Note that the value of employment in this stationary environment is given as:

$$V_{j+M|j}^E (0) = v(w) + \delta V_{j+M|j}^E (0).$$

which immediately implies that:

$$V_{j+M|j}^E (0) = \frac{1}{1-\delta} v(w) \tag{5}$$

Backwards induction to solve for optimal consumption path during employment One can use equation (4) together with equation (5) to solve for the value of accepting a job in period j, via backwards inducation. Plugging the budget constraint into equation (4)

$$V_{t|j}^E (A_t) = \max_{A_{t+1}} u\left(A_t + y_t - \frac{A_{t+1}}{1+R} \middle| r_t \right) + \delta V_{t+1|j}^E (A_{t+1}). \tag{6}$$

Note that the utility function has a kink at the reference point, so that one has to be careful using the first order conditions. Specifically, an Euler equation will determine the consumption path at employment on either side of the reference point but will break once there is a crossing of consumption and reference point In practice we solve this problem numerically whenever there is potential for crossing, such that we find the optimal value of A_{t+1} for each possible value of A_t and then calculate the value of employment in period t using equation (6).

1.2.4 Solving for the optimal search effort and consumption path during unemloyment

General first order conditions Substituting the budget constraint into equation (3):

$$V_t^U (A_t) = \max_{s_t \in [0,1]; A_{t+1}} u\left(A_t + y_t - \frac{A_{t+1}}{1+R_t} | r_t \right) - c(s_t) + \delta \left[s_t V_{t+1|t+1}^E (A_{t+1}) + (1-s_t) V_{t+1}^U (A_{t+1}) \right]$$

The first order condition for s_t is given as

$$c'(s_t) = \delta \left[V_{t+1|t+1}^E (A_{t+1}) - V_{t+1}^U (A_{t+1}) \right] \tag{7}$$

---

[2]This will hold if $\delta \leq \frac{1}{1+R}$, which is the case in all of our estimations.

which, given that $c(.)$ is invertible, directly determines the optimal search effort s_t as a function of: $V_{t+1|t+1}^E (A_{t+1})$ and $V_{t+1}^U (A_{t+1})$ and therefore as a function of A_{t+1}. If we write the mapping from future assets to the optimal search effort as $s_t^*(A_{t+1})$, then the value function can be written as:

$$V_t^U(A_t) = \max_{A_{t+1}} u\left(A_t + y_t - \frac{A_{t+1}}{1+R_t}|r_t\right) - c\left(s_t^*(A_{t+1})\right) + \delta\left[s_t^*(A_{t+1})V_{t+1|t+1}^E (A_{t+1}) + (1 - s_t^*(A_{t+1})) V_{t+1}^U (A_{t+1})\right]$$
(8)

This can either be solved numerically in a discrete asset space.

Stationary environment in unemployment: Once an individual is unemployed and a stationary environment $t \geq S$ is reached, we have that: $r_S = c_S = y_S$ and $A_S = A_t = A_{t+1} = -L$, where $-L$ is the lower bound of the asset space if an individual is impatient enough (or the interest rate low enough) such that $\delta < \frac{1}{1+R}$. This implies that the value function of unemployment simplifies to:

$$V_S^U(0) = \max_{s_S \in [0,1]; A_S} v\left(b_S\right) - c\left(s_S\right) + \delta\left[s_S V_{S|S}^E (L) + (1 - s_S) V_S^U (L)\right]$$
(9)

In this case the first order condition for search intensity simplifies to:

$$c'(s_S) = \delta\left[V_{S|S}^E (0) - V_S^U (0)\right]$$
(10)

Backwards induction Going backwards from the steady state we can solve for the optimal consumption path and search effort during unemployment using equations (7) and (8).

1.3 Model with Present Bias

The naive present biased individual is present biased when it comes to the trade-off between current period search effort and consumption and the future return to search. The individual is naive in the sense that she assumes that in the future she will not be present biased and choose a consumption and search effort path as if she were a standard exponential discounter.

The individual has the following value function in unemployment:

$$V_t^{U,n}(A_t) = \max_{s_t \in [0,1]; A_{t+1}} u\left(c_t|r_t\right) - c\left(s_t\right) + \beta\delta\left[s_t V_{t+1|t+1}^E (A_{t+1}) + (1 - s_t) V_{t+1}^U (A_{t+1})\right]$$
(11)

where the functions V_{t+1}^U and $V_{t+1|t+1}^E$ are given by equations (3) and (4) above for the exponential discounters and the budget constraint is the same.

This adds one more step to the solution algorithms, since we first solve for all possible values of V_{t+1}^U and $V_{t+1|t+1}^E$ and then we solve for the optimal consumption and search path given by $V_{t+1}^{U,n}$ and $V_{t+1|t+1}^{E,n}$. Note that in practice we never have to solve for the optimal consumption path of the present biased individual, since only her (naively) predictedexponential consumption path enters the decision making process during unemployment. For completeness sake, the value function during

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employment for the naive present biased individual is provided here and could be used to solve for the consumption path in employment:

$$V_{t+1|t+1}^{E,n} (A_{t+1}) = \max_{A_{t+1}>0} u (c_t|r_t) + \beta\delta V_{t+2|t+1}^{E} (A_{t+1}) \tag{12}$$

1.4 Hand to Mouth Model

In the hand to mouth model we have that $c_t = b_t$ when unemployed and $c_t = w$ when employed.

Note that the reference point at time t depends only on whether a worker is unemployed or, if employed, when a worker found a job. To make this distinction explicit, let's denote r_t the reference point in period t if the individual was unemployed until period $t-1$ (i.e. the individual started a job in period t), and let's denote r_t^j the reference point of an individual in period t who started a job in period j.

The value functions simplify to:

$$V_t^U = \max_{s_t\in[0,1]} u (b_t|r_t) - c (s_t) + \delta \left[s_t V_{t+1}^E + (1 - s_t) V_{t+1}^U \right] \tag{13}$$

$$V_{t+1}^E = \frac{v (w)}{1 - \delta} + \eta \sum_{i=1}^{N} \delta^i \left[v (w) - v \left(r_{t+i}^{t+1} \right) \right].$$

The FOC for optimal search effort is given as:

$$c' (s_t^*) = \delta \left[V_{t+1}^E - V_{t+1}^U \right]. \tag{14}$$

The assumptions on c(.) imply that $c'(.)$ is invertible and the inverse is differentiable, such that we can define $\mathcal{C}(.) \equiv c'^{-1}(.)$ and thus have that the optimal search effort is given as:

$$s_t^* = \mathcal{C} \left(\delta \left[V_{t+1}^E - V_{t+1}^U \right] \right)$$

Furthermore let $\Delta V_{t+1} \equiv V_{t+1}^E - V_{t+1}^U$. Taking derivatives of the FOC we get:

$$\frac{ds_t^*}{db_j} = \frac{d\Delta V_{t+1}}{db_j} \delta\mathcal{C}' (\Delta V_{t+1})$$

Note that as long as the reemployment wage is always above the level of UI benefits ΔV_{t+1} is always strictly greater than zero. Furthermore, given that the cost function $c(.)$ is strictly increasing, the inverse has to be increasing and therefore $\mathcal{C}' (\Delta V_{t+1}) > 0$.

1.4.1 Proof of Proposition 1

We want to prove that in the reference-dependent model $\frac{ds_{T+i}^*}{db_1} \leq 0$, for $i = 0, 1, ...N - 1$. Since $\mathcal{C}' (\Delta V_{t+1}) > 0$, this is the case as long as $\frac{d\Delta V_{T+i}}{db_1} \leq 0$. Note that $\frac{dr_{T+i}}{db_1} \leq 0$ and $\frac{dr_{T+i+j|T+i}}{db_1} \leq 0$, for

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all $j > 0$. We will show that $\frac{d\Delta V_{T+i}}{db_1} \leq 0$ by rewriting the terms $\frac{dV_{T+i}^E}{db_1}$ and $\frac{dV_{T+i}^U}{db_1}$ and showing that the sum is weakly smaller than 0.

Let us define the probability that an individual who is unemployed in period t is still unemployed j periods later: $\beta_{t,j} \equiv \Pi_{k=1}^{j}(1 - s_{t+k-1})$, and $\beta_{t,0} \equiv 1$.

Consider the effect of an increase in b_1 on the value of employment in period $T + i$:

$$
\begin{aligned}
\frac{dV_{T+i}^E}{db_1} &= \sum_{j=0}^{N-1} \delta^j \frac{du\left(w|r_{T+i+j}^{T+i}\right)}{db_1} \\
&= \frac{du\left(w|r_{T+i}^{T+i}\right)}{db_1} + \sum_{j=1}^{N-1} \delta^j \frac{du\left(w|r_{T+i+j}^{T+i}\right)}{db_1}
\end{aligned}
$$

The utility function is not differentiable at $r_t = b_t$ due to the kink. This is a minor technical issue and the following derivation holds if a) we assume the unemployed are always at a loss and the employed at a gain or b) if all derivatives are interpreted as right derivatives.

Similarly, it is helpful to write out $\frac{dV_{T+i}^U}{db_1}$ as the summation of all the possible nodes that can be reached in the probability tree and then sum them up. Using the envelope theorem, the effect of b_1 on s_t does not have a first order effect on the value of unemployment and we can write:

$$
\begin{aligned}
\frac{dV_{T+i}^U}{db_1} &= \frac{du(b_{T+i}|r_{T+i})}{db_1} + \ldots \\
&\quad \delta\beta_{T+i,1}\frac{du(b_{T+i+1}|r_{T+i+1})}{db_1} + \delta\beta_{T+i,0}s_{T+i}\frac{du(w|r_{T+i+1}^{T+i+1})}{db_1} + \ldots \\
&\quad \delta^2\beta_{T+i,2}\frac{du(b_{t+3}|r_{T+i+2})}{db_1} + \delta^2\beta_{T+i,0}s_{T+i}\frac{du(w|r_{T+i+2}^{T+i+1})}{db_1} + \delta^2\beta_{T+i,1}s_{T+i+1}\frac{du(w|r_{T+i+2}^{T+i+2})}{db_1} + \ldots \\
&\quad \delta^3\beta_{T+i,3}\frac{du(b_{t+4}|r_{T+i+3})}{db_1} + \delta^3\beta_{T+i,0}s_{T+i}\delta\frac{du(w|r_{T+i+3}^{T+i+1})}{db_1} + \delta^3\beta_{T+i,1}s_{T+i+1}\frac{du(w|r_{T+i+3}^{T+i+2})}{db_1} + \delta^3\beta_{T+i,2}s_{T+i+1}\frac{du(w|r_{T+i+3}^{T+i+3})}{db_1} + \ldots \\
&= \frac{du(b_{T+i}|r_{T+i})}{db_1} + \sum_{j=1}^{N-1} \delta^j \left[\beta_{T+i,j}\frac{du(b_{T+i+j}|r_{T+i+j})}{db_1} + \sum_{k=1}^{j}\beta_{T+i,k-1}s_{T+i+k}\frac{du(w|r_{T+i+j}^{T+i+k})}{db_1}\right]
\end{aligned}
$$

Notice that for all j we have that:

$$
\beta_{T+i,j} + \sum_{k=1}^{j}\beta_{T+i,k-1}s_{T+i+k} = 1,
$$

since this is simply the sum of all probabilities of where an individual is in the possible employment-unemployment path tree in period j conditional on being unemployed at the beginning of t.

Now we can combine the two terms to get $\frac{d\Delta V_{T+i}}{db_1}$:

$$
\frac{d\Delta V_{T+i}}{db_1} = \frac{dV_{T+i}^E}{db_1} - \frac{dV_{T+i}^U}{db_1}
$$

$$
= \quad \frac{du\left(w|r_{T+i}^{T+i}\right)}{db_1} + \sum_{j=1}^{N-1} \delta^j \frac{du\left(w|r_{T+i+j}^{T+i}\right)}{db_1}
$$

$$
- \frac{du(b_{T+i}|r_{T+i})}{db_1} - \sum_{j=1}^{N-1} \delta^j \left[\beta_{T+i,j} \frac{du(b_{T+i+j}|r_{T+i+j})}{db_1} + \sum_{k=1}^{j} \beta_{T+i,k-1} s_{T+i+k} \frac{du(w|r_{T+i+j}^{T+i+k})}{db_1} \right]
$$

Note that: $\frac{du\left(w|r_t^j\right)}{db_1} = -\eta \frac{dv\left(r_t^j\right)}{db_1} = -\eta v'\left(r_t^j\right)\frac{dr_t^j}{db_1}$ and $\frac{du(b_t|r_t)}{db_1} = -\lambda\eta\frac{dv(r_t)}{db_1} = -\lambda\eta v'(r_t)\frac{dr_t}{db_1}$. There-fore:

$$
\frac{d\Delta V_{T+i}}{db_1} \quad = \quad -\eta v'\left(r_{T+i}^{T+i}\right)\frac{dr_{T+i}^{T+i}}{db_1} - \eta \sum_{j=1}^{N-1} \delta^j v'\left(r_{T+i+j}^{T+i}\right)\frac{dr_{T+i+j}^{T+i}}{db_1}
$$

$$
+ \eta\lambda v'(r_{T+i})\frac{dr_{T+i}}{db_1} + \eta\lambda \sum_{j=1}^{N-1} \delta^j \left[\beta_{T+i,j} v'(r_{T+i+j})\frac{dr_{T+i+j}}{db_1} + \sum_{k=1}^{j} \beta_{T+i,k-1} s_{T+i+k} v'\left(r_{T+i+j}^{T+i+k}\right)\frac{dr_{T+i+j}^{T+i+k}}{db_1} \right]
$$

Finally, if the benefit change b_1 affects only the benefit path prior to period $T + i$, as we presume in Proposition 1, then $\frac{dr_{T+i+j}^{T+i+i}}{db_1} = \frac{dr_{T+i+j}}{db_1} \leq 0$. We can therefore rewrite this as:

$$
\frac{d\Delta V_{T+i}}{db_1} \quad = \quad -\eta v'\left(r_{T+i}^{T+i}\right)\frac{dr_{T+i}}{db_1} - \eta \sum_{j=1}^{N-1} \delta^j v'\left(r_{T+i+j}^{T+i}\right)\frac{dr_{T+i+j}}{db_1}
$$

$$
+ \eta\lambda v'(r_{T+i})\frac{dr_{T+i}}{db_1} + \eta\lambda \sum_{j=1}^{N-1} \delta^j \left[\beta_{T+i,j} v'(r_{T+i+j})\frac{dr_{T+i+j}}{db_1} + \sum_{k=1}^{j} \beta_{T+i,k-1} s_{T+i+k} v'\left(r_{T+i+j}^{T+i+k}\right)\frac{dr_{T+i+j}}{db_1} \right] \quad (15)
$$

Because the UI benefit path non-increasing, the reference point is also non-increasing over the UI spell. This in turn implies that: $r_{T+i+j}^{T+i} \geq r_{T+i+j}^{T+i+1} \geq r_{T+i+j}^{T+i+2} \geq \ldots$ and therefore, since $v(.)$ is concave, that $v'\left(r_{T+i+j}^{T+i}\right) \leq v'\left(r_{T+i+j}^{T+i+1}\right) \leq \ldots$. Furthermore: $v'(r_{T+i}^{T+i}) < v'(r_{T+i})$.

We can substitute these terms in the second line of equation (15) to get the following inequality:

$$
\frac{d\Delta V_{T+i}}{db_1} \quad < \quad -\eta v'\left(r_{T+i}^{T+i}\right)\frac{dr_{T+i}}{db_1} - \eta \sum_{j=1}^{N-1} \delta^j v'\left(r_{T+i+j}^{T+i}\right)\frac{dr_{T+i+j}}{db_1}
$$

$$
+ \eta\lambda v'\left(r_{T+i}^{T+i}\right)\frac{dr_{T+i}}{db_1} + \eta\lambda \sum_{j=1}^{N-1} \delta^j \left[\beta_{T+1,j} v'\left(r_{T+i+j}^{T+i}\right)\frac{dr_{T+i+j}}{db_1} + \sum_{k=1}^{j} \beta_{T+i,k-1} s_{T+i+k} v'\left(r_{T+i+j}^{T+i}\right)\frac{dr_{T+i+j}}{db_1} \right]
$$

$$
= \quad -\eta v'\left(r_{T+i}^{T+i}\right)\frac{dr_{T+i}}{db_1} - \eta \sum_{j=1}^{N-1} \delta^j v'\left(r_{T+i+j}^{T+i}\right)\frac{dr_{T+i+j}}{db_1}
$$

$$
+ \eta\lambda v'\left(r_{T+i}^{T+i}\right)\frac{dr_{T+i}}{db_1} + \eta\lambda \sum_{j=1}^{N-1} \delta^j \left[v'\left(r_{T+i+j}^{T+i}\right)\frac{dr_{T+i+j}}{db_1} \left(\beta_{T+i,j} + \sum_{k=1}^{j} \beta_{T+i,k-1} s_{T+i+k} \right) \right]
$$

$$
= \quad -\eta \sum_{j=0}^{N-1} \delta^j v'\left(r_{T+i}^{T+i}\right)\frac{dr_{T+i}}{db_1}
$$

$$
+ \eta\lambda \sum_{j=0}^{N-1} \delta^j v'\left(r_{T+i+j}^{T+i}\right)\frac{dr_{T+i+j}}{db_1}
$$

$$
= \quad \eta \left((\lambda - 1) \sum_{j=0}^{N-1} \delta^j v'\left(r_{T+i+j}^{T+i}\right)\frac{dr_{T+i+j}}{db_1} \right)
$$

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Therefore if $\lambda > 1$ and $\frac{dr_{T+i+j}}{db_1} \leq 0$ for at least one $j < N$ we have $\frac{d\Delta V_{T+i}}{db_1} \leq 0$ and therefore $\frac{ds_{T+i}}{db_1} \leq 0$. Therefore frontloading UI benefits by increasing b_1 and reducing b_2, leads to a decrease in search effort in period T, $T+1$, ... $T+N-1$. This is in contrast to the standard model where frontloading benefits will only affect search effort in period $T-1$ and earlier.

Since $\frac{dr_{T+i}}{db_1} < 0$ for $i = 0, 1, ...N-1$, this proves Proposition 1.

2 Estimation

2.1 Reducing the Dimensionality of the Endogenous Savings Model from $|A|^2$ to $|A|$

In order to find the optimal consumption and search effort path we need to find the value functions (either at employment or unemployment) for every t for each pair of (A_t, A_{t+1}) and then find the optimal $A^*_{t+1}(A_t)$ that maximizes the value. In practice, we discretize the asset space to be of size $|A| = L$, so $A_t \in \left\{ A^1, A^2, ..., A^L \right\}$.

It is then clear that the problem becomes of complexity of L^2 for every period t, which is highly demanding. But, we can reduce the complexity to be linear in L. Imagine you solved for the state variable A^l_t, obtaining the optimal $A^*_{t+1}(A^l_t)$. When considering the adjacent state variable, A^{l+1}_t, the optimal $A^*_{t+1}(A^{l+1}_t)$ will likely be in the neighborhood of $A^*_{t+1}(A^l_t)$. In practice, we find the global maximum for $A^*_{t+1}(A^l_t)$;[3] then, for $A^*_{t+1}(A^{l+1}_t)$ we search for the numerical maximum only for A_{t+1}'s in a fixed size bandwidth around $A^*_{t+1}(A^l_t)$; if the maximum lies on the boundary of the bandwidth, we search again for the global maximum. This method is applied for both the value of employment and of unemployment.

We use a state space with increments of 10 and allow for 50 possible values in the baseline models (i.e. asset values of 0, 10, 20, ... 490). We carefully check whether we get close to the upper bound of the state space in each estimation run and if so increase the state space.

2.2 Optimization Algorithm

We estimate the model in matlab and use the matlab optimizer fmincon to find the vector of parameters that minimizes the objective function. We set the following optimization options:

- Maximum function evaluations: 3000

- Maximum iterations: 3000

- Function tolerance: 10^{-12}

- X tolerance: 10^{-9}

- Algorithm: interior-point

- Large scale: off

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[3]We also find the global maximum for $l = 1$ and for some additional intermediates $1 < l < L$ to verify we are not erring.

When estimating the model we draw starting values for each paramter from uniform distributions with upper and lower bounds that are wide but roughly economically reasonable, for example a γ between 0.1 and 1.3. We restrict the values of some parameters within an economically plausible range, for example $N < 800$ (days), $0 < \gamma \leq 50$, $\lambda < 30$, and $\beta \geqslant 0.01$.[4] We estimate each model using at least 200 random draws of starting values and carefully check convergence. In most cases the best 10 to 20 runs all converge to the same or virtually the same solutions. For some models convergence is less reliable and we increase the number of initial starting values.

Running time for a single specification on a server using 12 cores is usualy at the the range of 8-16 hours. It depends on the number of types, and of course the number of parameters. Without the dimensionality reduction procedure described above, each run would have taken weeks to converge.

Another method we used to improve convergence was to do a two stage estimation. First, we draw a large number (e.g. 200) of initial values from a uniform distribution with a large yet reasonable support of parameter values. Second, we draw a lower number (e.g. 20 or 50) of initial values from a tighter support around the first stage best estimates (e.g. $\pm 20\%$ of first-stage best estimates). This method improves the fit considerably in a few cases, but mostly has very minor effects.

Standard errors are computed by inverting the numerically calculated Hessian matrix at the optimal solution.

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[4]In the reference dependent model with heterogneity in reemployment wages (Table 7, Column 5), we used the restriction $\beta \geq 0.1$, since otherwise we still ended up with an implausibly low estimate for β, though qualitatively the results were similar.

Web Appendix

Table WA-1: Predicting non-employment durations and reemploment wages for test of dynamic selection

| | Non-employment duration | | Log Reemployment Wages | |
| | Pre-reform | Post-reform | Pre-reform | Post-reform |
	(1)	(2)	(3)	(4)
Completed vocational school	-39.98***	-31.49***	0.037	0.091***
	(8.25)	(8.95)	(0.03)	(0.029)
Completed secondary school	-30.02***	-15.26	0.11***	0.150***
	(8.86)	(9.64)	(0.03)	(0.03)
Completed tertiary education	-49.10***	-40.79***	0.42***	0.44***
	(11.64)	(11.77)	(0.04)	(0.038)
Age between 30-34	7.12	22.48***	-0.002	-0.003
	(7.40)	(8.13)	(0.02)	(0.025)
Age between 35-39	10.85	31.44***	-0.013	-0.004
	(7.57)	(8.31)	(0.02)	(0.03)
Age between 40-44	19.76**	29.53***	-0.014	-0.014
	(7.95)	(8.84)	(0.02)	(0.028)
Age between 45-49	30.24***	51.25***	-0.007	-0.022
	(7.82)	(8.64)	(0.02)	(0.027)
Female	6.55	12.48**	-0.068***	-0.094***
	(5.79)	(6.22)	(0.02)	(0.020)
Waiting period	0.44***	0.49***	0.000	-0.0005**
	(0.07)	(0.07)	(0.0002)	(0.0002)
Log-earnings in 2002	6.66	17.43	0.039	0.04
	(11.31)	(11.88)	(0.04)	(0.04)
Log-earnings in 2003	-33.14***	-52.86***	0.19***	0.20***
	(10.43)	(10.76)	(0.03)	(0.03)
Observations	6,305	5,562	5,460	4,678
R-squared	0.048	0.059	0.155	0.177
Panel B predicted percentiles				
5th percentile	228	206	11.05	11.17
25th percentile	264	247	11.19	11.27
median	291	280	11.3	11.39
75th percentile	320	313	11.48	11.59
95th percentile	366	362	11.83	11.93

Notes:
Non-employment durations are capped at 540 days. The estimates in columns (1) and (3) are based on the pre-reform period, the estimates in column (2) and (4) on the post reform period. The omitted category is males with finished elementary school, between 25 and 29 years. All columns control for the county of residence, day and the month when UI claimed claimed and occupation before job loss(1 digit) Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1
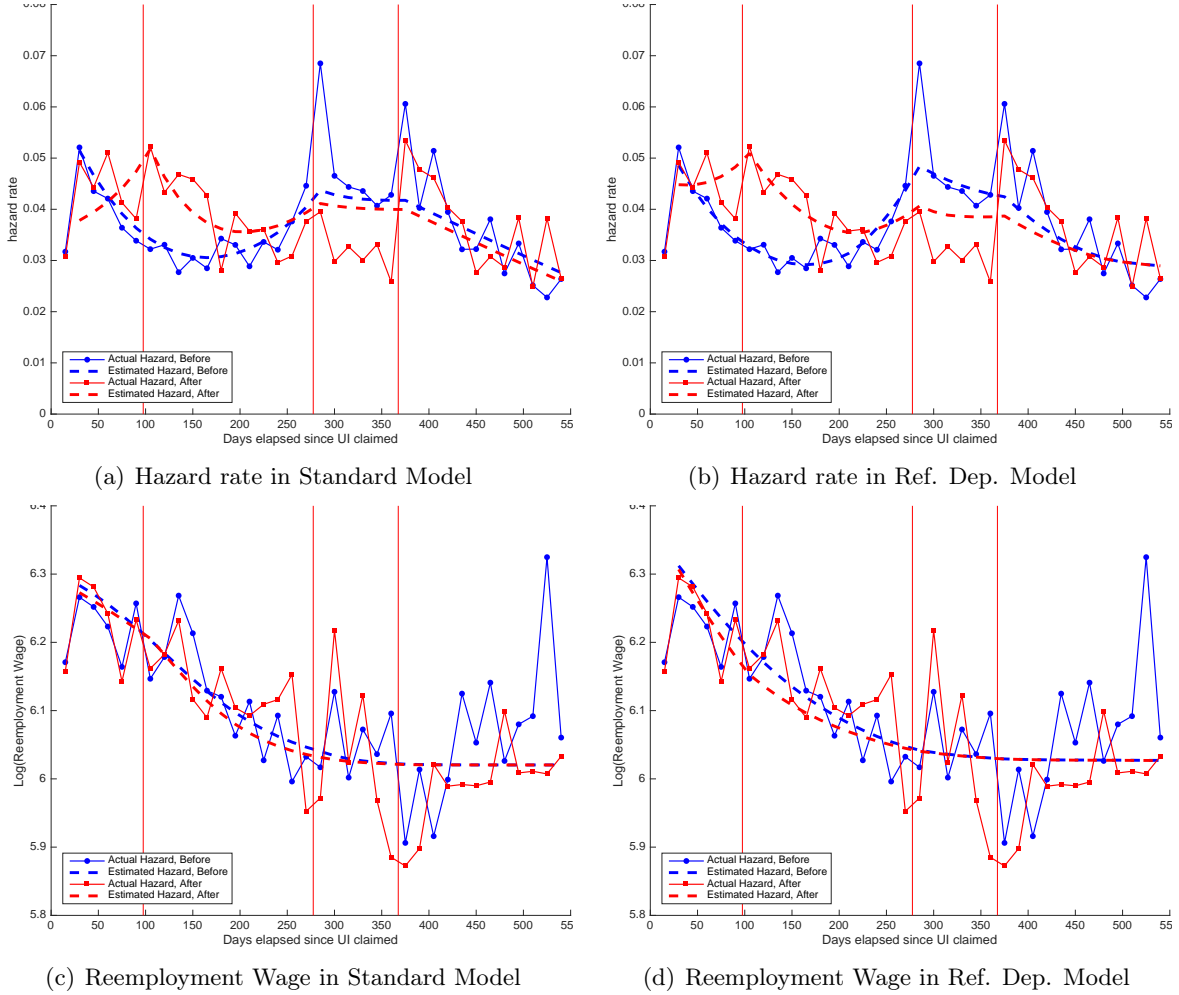
Table WA-2: Estimates with Reservation Wages

	Reservation Wage Model		HTM Model without Loss / Gain upon reemployment	
	Std Res. Wage	Ref. Dep. Res. Wage	Std HTM	Ref. Dep. HTM
	(1)	(2)	(3)	(4)
Parameters of Utility Function				
Loss aversion λ		1.38 (0.19)		2.16 (0.40)
Adjustment speed of reference point N		210.0 (16.4)		216.2 (17.9)
Discount factor (15 days) δ	0.98 (0.02)	0.97 (0.01)	0.97 (0.06)	0.92 (0.02)
Log reemployment wage	6.00 (0.01)	6.02 (0.01)		
Sd of log reemploment wage	0.5	0.5		
Parameters of Cost Function				
Curvature of search cost γ	0.15 (0.14)	0.22 (0.10)	0.13 (0.26)	0.54 (0.16)
Search cost for high cost type k_{high}	668583.9 (.)	103.7 (12.7)	127.0 (153.3)	141.2 (43.0)
Search cost for medium cost type k_{med}	76.2 (39.5)		75.9 (118.6)	
Search cost for low cost type k_{low}	14.5 (10.6)	0.0 (1.3)	26.5 (45.7)	12.2 (5.3)
Share of low cost UI claimant	0.22 (0.02)	0.10 (0.09)	0.17 (0.04)	0.02 (0.01)
Share of medium cost UI claimant	0.61 (0.03)		0.49 (0.16)	
Model Fit				
Number of moments used	140	140	70	70
Number of estimated parameters	8	8	7	7
Goodness of fit (SSE)	308.1	272.3	215.2	170.1
SSE in hazard moments	218.2	177.2		

Notes:
The table shows estimates of the standard and reference dependent model with reservation wages and hand-to-mouth consumers in columns (1) and (2), assuming no loss/gain utility upon reemployment. All models assume a log utility function for the flow utility. For comparison, columns (3) and (4) show the hand-to-mouth standard and reference-dependent model with loss/gain utility shut down. Furthermore we show the goodness of fit statistic for all moments (hazard and reemployment wage moments, as well as for only the hazard moments to make it easier to compare with the non-reservation wage model.

Figure WA-1: Structural Estimation Incorporating Reservation Wages

(a) Hazard rate in Standard Model

(b) Hazard rate in Ref. Dep. Model

(c) Reemployment Wage in Standard Model

(d) Reemployment Wage in Ref. Dep. Model

Notes: The figure shows the empirical hazards and the predicted hazards for estimations of the standard model and reference dependent model incorporating reservation wages and using reemployment wages by unemployment duration as additional moments. The figure corresponds to the columns (1) and (2) in Table WA-2.