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## Job Search and the Age-Inequality Profile

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# Job Search and the Age-Inequality Profile

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## Abstract

The variance of wages is U-shaped in age. To explain this outcome, I introduce endogenous search effort and a fixed retirement age into Cahuc, Postel-Vinay, and Robin's (2006) strategic wage bargaining model with counteroffers and heterogeneous firm-worker matches. Three factors shape the age-inequality profile of wages in the model economy: the time until retirement, match heterogeneity, and the worker's bargaining power. Because the working life is finite, the optimal search effort decreases with age and this leads to the increase in the variance of wages among older workers. Furthermore, the probability to meet an outside firm with a higher match quality decreases in the quality of the current match. The model can reproduce the U-shape of the age-inequality profile of wages if the bargaining power of workers is sufficiently high. The model also captures the shapes of the observed age profiles of average wages, the unemployment to employment transition rate, and the employment to employment transition rate.

**JEL classification:** J31; J41; J64

**Keywords:** Search Frictions, Wage Dispersion, Life Cycle, Wage Bargaining

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# 1 Introduction

The variance of log wages across workers follows a U-shape with age (Mincer, 1974; Heckman, Lochner, and Todd, 2003). The variance is high for young workers who have just entered the labor market. As workers grow older, it decreases at first and starts to increase again in the second half of the working life. Understanding the sources of lifetime wage inequality is necessary for the design of welfare policies and insurance programs. Furthermore, the age structure of the population might be an important factor behind differences in income inequality between countries or changes in the wage structure across time. The objective of this paper is to explore the driving forces of the age-inequality profile in a search model of the labor market.

There are different explanatory approaches to the U shape of the age-inequality profile. Differing age-tenure profiles are one potential source. Another approach attributes the high residual wage dispersion of young and old workers to investment in human capital accumulation (Mincer, 1974).<sup>1</sup> Rubinstein and Weiss (2006) explore the implications of the human capital investment model and a search model of the labor market for life cycle wages. They find empirical support for both theories. While they argue that a search model alone cannot give rise to a U-shaped age-inequality profile, the present paper shows that search theory is sufficient to explain the U-shape. Search frictions and employment to employment transitions are potentially important determinants of residual wage dispersion (Postel-Vinay and Robin, 2002; Tjaden and Wellschmied, 2012). Furthermore, the employment to employment transition rate decreases with age (Menzio, Telyukova, and Visschers, 2012). This suggests to explore the age-inequality profile in conjunction with on-the-job search.

I introduce endogenous search effort and a finite working life into the bargaining model of Cahuc, Postel-Vinay, and Robin (2006). Firm-worker matches have different productivities, workers search on and off the job, and incumbent employers can counter outside wage offers. The optimal search behavior of employed workers depends on the worker's age, the current wage, and the quality of the firm-worker match. Hence, the search effort is high for young workers and decreases with age. I show that the present model captures the

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<sup>1</sup>Workers who invest in human capital on-the-job early in their career earn initially a low wage. They are compensated by a high future wage. In such a model, the standard deviation is the lowest for middle-aged workers when the profiles of investors and non-investors cross.

shapes of the observed age profiles of average wages, the unemployment to employment transition rate, and the employment to employment transition rate.

A large fraction of the life cycle wage inequality in the model is driven by match heterogeneity. Indeed, the endogenous age-variance profile of match qualities is U-shaped. Search on and off the job leads to two opposing effects on wage dispersion. Because of employment to employment transitions, workers are gradually matched to better jobs and this decreases wage dispersion. Because of unemployment to employment transitions, there is a permanent flow of workers into the lower tail of the wage distribution. The first effect is dominant for young workers while the second effect dominates in the second half of the working life. The employment to employment transition rate decreases with age because workers reduce their search effort and because the probability to meet an outside firm with a higher match quality decreases in the quality of the current match. This implies that older workers upgrade their wages more slowly.

The U-shaped age-variance profile of match qualities only translates into a U-shaped age-variance profile of wages if workers' bargaining power is sufficiently high. The bargaining power is important because workers take into account the opportunity of future wage rises due to outside job offers. This option value of on-the-job search has a negative effect on workers' reservation wages. The shorter the remaining time until retirement, the lower is the option value of on-the-job search. If the workers' bargaining power is too low, the option value effect is too high for young workers and older workers' reservation wages increase strongly. The standard deviation of wages for workers close to retirement then decreases sharply. If the bargaining power of workers is sufficiently high, there is a modest increase in the reservation wage only for low quality matches prior to retirement. Apart from that, the reservation wage decreases for old workers since the probability of obtaining a better job offer by waiting decreases. Also the observed hump-shaped age profile of the average wage is only captured if the bargaining power of workers is sufficiently high. Otherwise the average wage increases sharply for workers close to retirement.

Related models with a finite working life and on-the-job search are Menzio, Telyukova, and Visschers (2012) and Jung and Kuhn (2012). Menzio, Telyukova, and Visschers (2012) develop a life cycle model with directed search and human capital accumulation. Their objective is to explain the age profile of worker transitions across employment states. Jung and Kuhn (2012) explore earnings losses after displacement for workers with high

tenure in conjunction with worker flows. I focus on the wage distribution for different age groups.

Other authors have explored the effect of a finite working life on labor market outcomes within a search theoretic model in which workers can only search when unemployed (Hairault, Sopraseuth, and Langot, 2010; Hahn, 2009; De la Croix, Pierrard, and Sneessens, 2009; Chéron, Hairault, and Langot, 2008). These models can explain the hump-shaped age profile of employment. Without additional assumptions, they imply a decreasing age-wage profile. In order to obtain the empirically observed increasing and concave age-wage profile, Hairault, Sopraseuth, and Langot (2010) calibrate age-specific wage offer distributions. De la Croix, Pierrard, and Sneessens (2009) assume that workers' productivities increase with age and then decrease as workers approach retirement. Chéron, Hairault, and Langot (2008) introduce human capital accumulation into their model.

This paper also relates to Bagger, Fontaine, Postel-Vinay, and Robin (2011) and Yamaguchi (2010), who also explore the driving forces of wage dynamics over the life cycle in a bargaining model with counteroffers. They focus on the importance of job search and human capital accumulation for individual wage growth in a model with an infinite time horizon, while I focus on the importance of job search and a finite working life for shaping the age-inequality profile of wages.

The paper is organized as follows: Section 2 describes the empirical age profile of wage inequality to be explained using the model framework set out in section 3. In section 4, I simulate the model economy and obtain age profiles of transition rates and age-inequality profiles. Section 5 discusses the mechanisms that shape the age-inequality profile of wages. Section 6 concludes.

## **2 The empirical age profile of wage inequality**

This section discusses the empirical age profile of wage inequality. I use the 1996 panel of the US Census' Survey of Income and Program Participation (SIPP), which spans the time period from December 1995 to February 2000.<sup>2</sup> The SIPP contains monthly data on the worker's employment status, earnings, primary job, and information on whether the

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<sup>2</sup>Data source: Center for Economic and Policy Research. 2012. SIPP Uniform Extracts, Version 2.1.7 . Washington, DC.

worker has changed the employer. I restrict the analysis to a subsample of non-unionized men between the ages of 18 and 66, whose highest educational attainment is a high school degree, and who do not have any income from self-employment. Furthermore, I do not consider any workers in the armed forces and workers who stop working for school or training reasons. The data set comprises 10,340 individuals and 242,159 observations.

Residual wages are derived from a fixed-effects regression of monthly log-wages on occupational dummies, a dummy for disabled workers, regional dummies, a dummy for marital status, and weekly hours. Time fixed effects are included. The estimated model is

$$\ln w_{it} = \alpha_i + \beta X_{it} + \varepsilon_{it},$$

where  $w_{it}$  is monthly earnings of worker  $i$  in period  $t$ ,  $\alpha_i$  is the unknown intercept for worker  $i$ ,  $\beta$  is a vector of coefficients,  $X_{it}$  is a vector of regressors, and  $\varepsilon_{it}$  is the error term. A description of the regressors and estimation results are presented in Appendix A.

The age-inequality profile is defined by the standard deviation of the residual,  $\hat{\varepsilon}_{it}$ , within each age group. The residual is determined by

$$\hat{\varepsilon}_{it} = \ln w_{it} - \widehat{\ln w_{it}},$$

where  $\widehat{\ln w_{it}}$  denotes the prediction of  $\alpha_i + \beta X_{it}$ . Figure 1 shows that the age-inequality profile is U-shaped. This result is robust to several alternative model specifications.<sup>3</sup> The main objective of the model developed in the next section is to provide an explanation of the U-shape.

### 3 A life cycle model with on-the-job search

The labor market is populated by a continuum of competitive firms and a unit mass of risk-neutral workers of different ages  $k = 1, 2, \dots, K$ . Time is discrete and the economy is in steady-state. Firms produce a unique multipurpose good, maximize profits, and live forever. Each worker lives a finite life of  $K$  periods. In steady-state, all workers that leave the labor market at age  $K + 1$  are replaced by unemployed workers of age 1. Hence, the fraction of the population aged  $k$  is given by  $l$  for all  $k < K$ .

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<sup>3</sup>A similar age-inequality profile is obtained if number of kids, age, age squared, and/or interaction between occupation and age are included, and if weekly hours is excluded.

Firm-worker matches differ in their productivities denoted as  $a_i$  with  $i = 1, \dots, n$  and  $a_{j-1} < a_j$ ,  $j = 2, \dots, n$ . The probability that a potential match has productivity  $a_i$  is given by  $p_i$ . The cumulative distribution of potential match qualities is denoted by  $P_i$ . When a firm and a worker meet, the quality of the potential match is revealed. For convenience, I describe a firm that offers a worker a match of quality  $a_i$  as a type  $i$  firm. Output per period in a firm-worker match does not depend on the worker's age and equals the marginal productivity of labor  $a_i$ . Unemployed workers receive an income flow of  $b_U$ . Workers derive utility from consumption and discount future utility at the factor  $\beta \in (0, 1)$ .

Workers search on and off the job. Searching for a job is costly for the worker. The cost of spending an effort  $e$  on searching is given by a cost function  $c(e)$ , with  $c(0) = 0$ . The cost function is increasing and strictly convex. The offer arrival rate per search effort is  $\lambda > 0$ . The search effort is derived endogenously by the worker's optimizing behavior. The timing of events is as follows. In the beginning of a period,  $g(k, a_i)$  workers aged  $k$  are employed at a match  $a_i$ . Each of these firm-worker matches is hit by an exogenous separation shock with probability  $\delta \in [0, 1]$ . Workers who become unemployed can immediately search for a new job that starts in the next period. The mass of unemployed workers of age  $k$  is then

$$u(k) = l - (1 - \delta) \sum_{j=1}^n g(k, a_j). \quad (1)$$

All workers that enter the labor market are unemployed, hence  $u(1) = l$ .

### 3.1 Wage bargaining

The wage formation rules are based on the bargaining model of Cahuc, Postel-Vinay, and Robin (2006). If an employed worker obtains an outside wage offer, the incumbent employer can counter the outside offer. Workers and employers have complete information over each other's type and over the worker's wage and job offers. Wage contracts specify a wage that can only be renegotiated by mutual agreement. Wage cuts within an employment are not possible. Consider a worker of age  $k$  employed at a type  $i$  firm earning wage  $w$ . When the worker contacts a type  $h$  firm, the incumbent and the poaching employer compete for the worker. The maximum wage a firm is able to offer equals the match productivity. The worker chooses the firm that offers the highest lifetime utility. The outcome of the bargaining process depends on the productivity of both firms and on the current

wage. Three cases can occur. If  $h > i$ , the worker switches to the poaching employer since the type  $h$  firm will offer the worker a wage that has a higher value than the highest wage the type  $i$  firm can offer. Note that the wage from the new employer can be smaller than  $w$  as the worker takes into account possible future wage rises. Such a wage cut is possible because of the option value of on-the-job search. An employment within a high productivity match gives the worker a better position for future wage negotiations. If  $h < i$ , the worker stays with the incumbent employer. The worker obtains a wage rise from the incumbent employer if and only if  $i \geq h \geq q(k, w, a_i)$ . If  $h$  is smaller than the threshold marginal productivity index  $q(k, w, a_i)$ , nothing changes for the worker. Table 1 gives an overview of the bargaining game.  $\phi(k, a_i, a_h)$  denotes the wage that is the outcome of a bargaining game between a type  $i$  firm and a type  $h$  firm, with  $h > i$ , and a worker of age  $k$ .

Table 1: Outcome of the wage bargaining game between a worker earning wage  $w$ , the incumbent employer of type  $i$ , and a poaching employer of type  $h$

|                              | <b>negotiation outcome</b>                              |
|------------------------------|---|
| $h > i$                      | new employer $h$ and a wage $\phi(k, a_i, a_h)$         |
| $i \geq h \geq q(k, w, a_i)$ | wage rise $\phi(k, a_h, a_i) - w$ from current employer |
| $h < q(k, w, a_i)$           | no change   |

The mechanisms of wage bargaining discussed so far are the same as in Cahuc, Postel-Vinay, and Robin (2006). However, while they assume that workers have an infinite life, workers leave the labor market at a given age in the present model. A young worker's wage bargain outcome is different than that of a worker close to retirement. The option value of on-the-job search makes workers accept a low starting wage. The shorter the time horizon before retirement, the lower is the option value of on-the-job search. Hence, it can occur that workers negotiate wage rises from the current employer without any outside job offer when they have a credible threat to quit into unemployment.

Let  $\mathcal{W}(k, w, a_i)$  denote the value of a job to a worker of age  $k$  earning wage  $w$  in a match with productivity  $a_i$ . When the two competing firms have productivities  $i$  and  $h$  with  $i < h$ ,

type- $h$  firm wins the bargain by offering a wage  $\phi(k, a_i, a_h)$  that is determined by

$$\mathcal{W}(k, \phi(k, a_i, a_h), a_h) = \mathcal{W}(k, a_i, a_i) + \gamma[\mathcal{W}(k, a_h, a_h) - \mathcal{W}(k, a_i, a_i)], \quad (2)$$

where the parameter  $\gamma \in [0, 1]$  is the worker's bargaining power. The worker obtains a value  $\mathcal{W}(k, \phi(k, a_i, a_h), a_h)$  that equals his outside option  $\mathcal{W}(k, a_i, a_i)$  - the highest value the lower productivity firm can offer - plus a share  $\gamma$  of the match surplus.

Consider a worker of age  $k$  earning wage  $w$  in a type  $i$  firm. The productivity index of the poaching firm must be at least equal to  $q(k, w, a_i)$  such that the worker obtains a higher lifetime utility in the bargaining game. Hence, the threshold productivity index  $q(k, w, a_i)$  is the lowest index for which

$$\begin{aligned} \mathcal{W}(k, w, a_i) &< \mathcal{W}(k, a_{q(k, w, a_i)}, a_{q(k, w, a_i)}) + \\ &\quad \gamma[\mathcal{W}(k, a_i, a_i) - \mathcal{W}(k, a_{q(k, w, a_i)}, a_{q(k, w, a_i)})] \end{aligned} \quad (3)$$

is fulfilled. It follows that  $q(k, a_i, a_i) = i + 1$ .

The outside option of an unemployed worker aged  $k$  is the value of unemployment denoted by  $\mathcal{U}(k)$ . A match between an unemployed worker and a type  $i$  firm is formed if and only if  $\mathcal{W}(k, a_i, a_i) \geq \mathcal{U}(k)$ . Provided this condition is satisfied, the firm offers a wage  $\phi_0(k, a_i)$  that solves

$$\mathcal{W}(k, \phi_0(k, a_i), a_i) = \mathcal{U}(k) + \gamma[\mathcal{W}(k, a_i, a_i) - \mathcal{U}(k)]. \quad (4)$$

A higher match quality offers the worker more opportunities to obtain wage rises because of possible outside job offers. This option value effect makes wages decrease in match quality. However, the higher the productivity of the firm that wins the bargain, the higher is the match surplus. The higher the worker's bargaining power, the more the worker captures of the match surplus. The bargaining power effect makes wages increase in match quality. In Cahuc, Postel-Vinay, and Robin (2006), wages decrease in the productivity of the firm that wins the bargain if  $\gamma$  is sufficiently small such that the option value effect dominates. If  $\gamma$  is large enough, the bargaining power effect dominates and wages increase in productivity. There are additional implications in a model with a finite time horizon. The shorter the remaining time horizon before retirement, the lower is the option value of on-the-job search.

### 3.2 Value functions

Each period, a worker decides how much effort  $e$  to spend on job search. The problem of an unemployed worker of age  $k < K - 1$  is summarized by

$$\mathcal{U}(k) = \max_{e \geq 0} \left\{ b_U - c(e) + \beta \left[ \mathcal{U}(k') + (1 - \delta)e\lambda \sum_{j=r(k')}^n [\mathcal{W}(k', \phi_0(k', a_j), a_j) - \mathcal{U}(k')] p_j \right] \right\},$$

where  $k' = k + 1$  and  $r(k')$  is the minimum productivity index of a match that a worker of age  $k'$  accepts. The reservation productivity  $a_{r(k')}$  is the lowest productivity level for which

$$\mathcal{W}(k', a_{r(k')}, a_{r(k')}) \geq \mathcal{U}(k')$$

holds. Since unemployed and employed workers face the same search cost function and the same offer arrival rate per search effort, the lowest acceptable match productivity for a worker equals the flow income when unemployed,  $b_U$ . In the remainder of the paper, I set

$$a_1 = a_{r(k)} = b_U.$$

Using equation (4), the value of unemployment becomes

$$\mathcal{U}(k) = \max_{e \geq 0} \left\{ b_U - c(e) + \beta \left[ \mathcal{U}(k') + (1 - \delta)e\lambda \gamma \sum_{j=1}^n [\mathcal{W}(k', a_j, a_j) - \mathcal{U}(k')] p_j \right] \right\}. \quad (5)$$

The optimal search effort of an unemployed worker aged  $k$ ,  $e_U(k)$ , is the solution to the first order condition (FOC) of the maximization problem

$$c'[e_U(k)] = \beta(1 - \delta)\lambda \gamma \sum_{j=1}^n [\mathcal{W}(k', a_j, a_j) - \mathcal{U}(k')] p_j. \quad (6)$$

The value of a job to a worker of age  $k < K - 1$  earning wage  $w$  in a match with productivity  $a_i$  is derived as follows:

$$\begin{aligned} \mathcal{W}(k, w, a_i) = \max_{e \geq 0} & \left\{ w - c(e) + \beta \left[ \delta \mathcal{U}(k') + (1 - \delta) \left[ \right. \right. \right. \\ & \left( 1 - e\lambda [1 - P_{q(k', w, a_i) - 1}] \right) \\ & \max \left\{ \mathcal{W}(k', w, a_i), \mathcal{U}(k') + \gamma [\mathcal{W}(k', a_i, a_i) - \mathcal{U}(k')] \right\} \\ & + e\lambda \sum_{j=q(k', w, a_i)}^i \left( \mathcal{W}(k', a_j, a_j) + \gamma [\mathcal{W}(k', a_i, a_i) - \mathcal{W}(k', a_j, a_j)] \right) p_j \\ & \left. \left. \left. + e\lambda \sum_{j=i+1}^n \left( \mathcal{W}(k', a_i, a_i) + \gamma [\mathcal{W}(k', a_j, a_j) - \mathcal{W}(k', a_i, a_i)] \right) p_j \right] \right] \right\}. \quad (7) \end{aligned}$$

The worker's value is the current wage minus search costs plus the discounted continuation value. The worker becomes unemployed and earns a value  $\mathcal{U}(k')$  with probability  $\delta$ . The employed worker does not meet an outside firm that has a productivity larger than  $a_{q(k', w, a_i) - 1}$  with probability  $1 - e\lambda(1 - P_{q(k', w, a_i) - 1})$ . In this case the worker stays in his current match. As the option value of on-the-job search decreases with age, the worker renegotiates the wage if  $\mathcal{W}(k', w, a_i)$  becomes smaller than  $\mathcal{U}(k') + \gamma[\mathcal{W}(k', a_i, a_i) - \mathcal{U}(k')]$ . If the worker meets an outside firm with lower productivity than  $a_i$  but above  $a_{q(k', w, a_i) - 1}$ , she expects a wage rise from the incumbent employer and a bargain outcome with value  $\sum_{j=q(k', w, a_i)}^i (\mathcal{W}(k', a_j, a_j) + \gamma[\mathcal{W}(k', a_i, a_i) - \mathcal{W}(k', a_j, a_j)]) p_j$ . If the worker meets an outside firm with match productivity larger than  $a_i$ , he switches to the poaching firm and expects a value  $\sum_{j=i+1}^n (\mathcal{W}(k', a_i, a_i) + \gamma[\mathcal{W}(k', a_j, a_j) - \mathcal{W}(k', a_i, a_i)]) p_j$ . Let  $e_W(k, w, a_i)$  denote the optimal search effort of a worker earning wage  $w$  at a type- $i$  firm. The optimal

search effort is the solution to the FOC

$$\begin{aligned}
c' [e_W(k, w, a_i)] = & \beta(1 - \delta)\lambda \left( \sum_{j=q(k', w, a_i)}^i \left[ (1 - \gamma)\mathcal{W}(k', a_j, a_j) + \gamma\mathcal{W}(k', a_i, a_i) \right] p_j \right. \\
& + \sum_{j=i+1}^n \left[ (1 - \gamma)\mathcal{W}(k', a_i, a_i) + \gamma\mathcal{W}(k', a_j, a_j) \right] p_j \\
& \left. - (1 - P_{q(k', w, a_i)-1}) \max \left\{ \mathcal{W}(k', w, a_i), \mathcal{U}(k') + \gamma [\mathcal{W}(k', a_i, a_i) - \mathcal{U}(k')] \right\} \right). \tag{8}
\end{aligned}$$

Alternatively, an employed worker's search effort could be chosen such that it is jointly efficient as in Lentz (2010). The corresponding employment contract specifies not only a wage but also the search effort that maximizes the joint surplus of the firm-worker match. However, the search effort that maximizes the joint surplus of a match of highest quality ( $a_n$ ) is zero. As a worker in a type  $n$  match cannot upgrade her wage under such a contract, an unemployed worker who obtains a job offer at a type  $n$  match earns always a lower wage than a worker who switches from a type  $i$  match with  $1 < i < n$  to a type  $n$  match. It is hard to justify the enforceability of zero search effort in this case. I therefore assume that a worker chooses the search effort to maximize his own value of the match.

Let  $\mathcal{R}(K)$  be the value of retirement.<sup>4</sup> A worker aged  $K - 1$  faces the following values:

$$\mathcal{U}(K - 1) = b_U + \beta\mathcal{R}(K) \tag{9}$$

$$\mathcal{W}(K - 1, w, a_i) = w + \beta\mathcal{R}(K) \tag{10}$$

### 3.3 Steady-state labor market flows

The labor market dynamics lead to the following distribution of workers across employment states. Let  $g(k, w, a_i)$  be the fraction of the population aged  $k$ , earning wage  $w$ , and being employed at a type  $i$  firm. The fraction of the population aged  $k$  being employed at a type  $i$  firm is given by  $g(k, a_i) = \int g(k, w, a_i)dw$ . The fraction of the population aged  $k'$  being employed at a type  $i$  firm is made up of the pool of unemployed workers that form a

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<sup>4</sup>The value of  $\mathcal{R}(K)$  has an effect only on the scale of the value functions but not on equilibrium wages or search efforts.

match with a type  $i$  firm, the workers that are recruited out of lower productivity jobs, and the workers that have stayed in a type  $i$  match:

$$\begin{aligned}
g(k', a_i) &= e_U(k) \lambda u(k) p_i \\
&+ (1 - \delta) \lambda p_i \sum_{j=1}^{i-1} \int e_W(k, w, a_j) g(k, w, a_j) dw \\
&+ (1 - \delta) \int [1 - e_W(k, w, a_i) \lambda (1 - P_i)] g(k, w, a_i) dw.
\end{aligned} \tag{11}$$

### 3.4 Wage distribution

Let  $G(w|k, a_i)$  be the cumulative distribution of wages conditional on age and productivity. The maximum wage a type  $i$  firm can offer is  $a_i$ . Hence

$$G(a_i|k, a_i) = 1.$$

All newborns are unemployed. Employed workers aged  $k = 2$  earn a wage  $\phi_0(2, a_i)$  since they were hired out of unemployment and have not yet searched on-the-job. The cumulative distribution of wages conditional on age and productivity for workers of age  $k' \geq 3$  is determined by

$$\begin{aligned}
G(w|k', a_i) &= I_{w \geq \phi_0(k', a_i)} \left\{ e_U(k) \lambda u(k) p_i \right. \\
&+ (1 - \delta) \lambda p_i \sum_{j=1}^{q(k', w, a_i) - 2} \int e_W(k, \tilde{w}, a_j) g(k, \tilde{w}, a_j) d\tilde{w} \\
&+ (1 - \delta) \int^w [1 - e_W(k, \tilde{w}, a_i) \lambda (1 - P_{q(k', w, a_i) - 1})] g(k, \tilde{w}, a_i) d\tilde{w} \left. \right\} \\
&/ g(k', a_i),
\end{aligned} \tag{12}$$

where  $I_{w \geq \phi_0(k', a_i)}$  is a dummy variable equal to 1 if  $w \geq \phi_0(k', a_i)$  and 0 otherwise. The conditional cumulative distribution of wages  $G(w|k', a_i)$  is the sum of unemployed workers with reservation wage  $\phi_0(k', a_i) \leq w$  who meet a type  $i$  firm, workers that switch from a lower productivity firm to a type  $i$  firm for a wage  $\leq w$ , and workers that stay in their current match of type  $i$  who do not earn a wage larger than  $w$ . Workers are only willing to switch to a type  $i$  firm for a wage  $\leq w$  if the match productivity of the current employment

is smaller than  $q(k', w, a_i)$ .<sup>5</sup> The cumulative distribution of wages conditional on age is determined by

$$G(w|k) = \frac{\sum_{j=1}^n G(w|k, a_j)g(k, a_j)}{g(k)}. \quad (13)$$

### 3.5 Equilibrium

A *stationary equilibrium* consists of

- a constant mass of employed workers  $g(k, a_i)$
- a constant mass of unemployed workers  $u(k)$
- the optimal search efforts  $e_U(k)$  and  $e_W(k, w, a_i)$
- wages  $\phi(k, a_i, a_h)$  and  $\phi_0(k, a_i)$
- the cumulative distribution functions of wages conditional on age and productivity  $G(w|k, a_i)$ ,

for all combinations of age  $k < K$  and match productivities  $a_i$ , given an exogenous productivity distribution, a constant mass of new workers of age  $k = 1$ , and the value of retirement  $\mathcal{R}(K)$ .

## 4 A quantitative analysis

In this section, I derive the equilibrium life cycle profiles of the unemployment to employment transition rate, the employment to employment transition rate and the wage distribution by simulating the model economy.

The definition of employment states and transition rates derived from the SIPP data follows Menzio, Telyukova, and Visschers (2012). A worker is assigned an employer based on his primary job where he worked the most hours. A worker is not in the labor force (N) if she reports having no job, not looking for work, and not being on layoff. A worker is unemployed (U) if she reports having no job and looking for work or being on layoff. A worker is employed (E) if she reports having a job and being either on

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<sup>5</sup>The index above the summation sign in equation (12) is set equal to  $q(k', w, a_i) - 2$  such that the equation fulfills  $G(a_i|k', a_i) = 1$  and equation (11).

layoff or not and absent without pay or not. A worker is in the labor force (L) if he is either employed or unemployed. The unemployment to employment transition (UE) rate is defined as the number of workers that experience a transition from unemployment to employment in a given month divided by the number of unemployed workers at the beginning of the month. The other transition rates are defined analogously.

The empirical rate at which employed workers become unemployed is decreasing with age (see Figure 2). Furthermore, the data shows that there are workers who flow in and out of the labor market across all age groups (see Figures 3 to 6). These transitions influence the wage distribution and are therefore taken into account when calibrating the model. Figure 7 shows how these labor market dynamics enter the model simulation. Simulation details are provided in Appendix B.

## 4.1 Calibration

One period in the simulation refers to one month. I therefore set the discount factor  $\beta = 0.9967$ . Workers retire after 49 years in the labor market, i.e.  $K = 588$ . The distribution of match qualities is Weibull with scale parameter  $\phi = 5$ , shape parameter  $\tau$ , and a location parameter that equals  $b_u$ . The number of grid points is  $n = 40$ . The cost of spending an effort  $e$  on searching is given by the quadratic cost function<sup>6</sup>

$$c(e) = ce^2.$$

I set  $c = 0.5$ .<sup>7</sup> The parameters  $\gamma$ ,  $\lambda$ ,  $\tau$ , and  $b_U (= a_1)$  are chosen such that they minimize the distance between simulated moments and corresponding moments obtained from the SIPP 1996 panel. I use 53 estimation targets: Average wages within each age group (49 targets), the standard deviation of residual wages, the EE rate, the UE rate, and the skewness of the wage distribution. The age-wage profile contains information on the life cycle profile of reservation wages and thereby on the bargaining power parameter  $\gamma$ . The estimate of the

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<sup>6</sup>Christensen, Lentz, Mortensen, Neumann, and Werwatz (2005) estimate a model with on-the-job search in which the search effort is endogenous and the offer arrival rate per search effort is the same for employed and unemployed workers. Their results support a quadratic cost of search function.

<sup>7</sup>The FOCs (6) and (8) show that  $\lambda$  and  $c$  cannot be identified separately but only the ratio  $\lambda/c$ . One can either set a value to  $c$  and then calibrate the parameter  $\lambda$  or the other way around.

vector of structural parameters  $\theta = (\gamma, \lambda, \tau, b_U)$  minimizes

$$(G^d - G^s(\theta))' \times I \times (G^d - G^s(\theta)), \quad (14)$$

where  $G^d$  is a  $53 \times 1$  vector containing the target moments from the data,  $G^s$  is a  $53 \times 1$  vector of moments produced from model simulation, and  $I$  is a  $53 \times 53$  identity matrix. Table 2 contains the calibration targets and table 3 the estimated parameters.

Table 2: Calibration Targets

| Target                  | Data     | Model   |
|-------------------------|----------|---------|
| Age-wage profile        | Figure 8 |         |
| St.d. of residual wages | 0.4379   | 0.4377  |
| Average UE rate         | 0.1685   | 0.1793  |
| Average EE rate         | 0.0154   | 0.0151  |
| Skewness                | -2.5406  | -1.7190 |

Table 3: Point Estimates

| Description                          | Parameter | Estimate |
|--------------------------------------|-----------|----------|
| Workers' bargaining power            | $\gamma$  | 0.7172   |
| Offer arrival rate per search effort | $\lambda$ | 0.0600   |
| Shape parameter                      | $\tau$    | 1.8500   |
| Flow income of unemployment          | $b_U$     | 0.0501   |

## 4.2 Life cycle profiles

Figure 9 displays the life cycle profiles of the empirical and of the model UE rate. The UE rate remains relatively constant until a few years before retirement, then declines dramatically as workers reduce their search effort substantially when they approach the retirement age. Searching for a job is costly and the expected value of a job offer is small for workers close to retirement. The model UE rate slightly increases until age 48 because the rate at which workers quit employment decreases until this age group. This decrease has a

positive effect on the value of a job.

The life cycle profile of the EE rate decreases with age (see Figure 10). The decreasing EE age profile is the result of two effects. A worker's search history increases with age and so does the average match quality. The probability of obtaining a better match decreases in the quality of the current match. Furthermore, older workers reduce their search effort since the remaining time horizon in the labor market shortens. The EE rate approaches zero for workers close to retirement because these workers reduce the search effort substantially. The simulated EE rate matches the empirical one well. Compared with the data, the EE rate obtained from the simulation declines sharply for old workers as all workers retire at the same age in the model economy.

Let us turn to the standard deviation of wages illustrated in Figure 11. The age-inequality profile of wages is U-shaped. The age-inequality profile falls for young workers because the EE rate is high for this age group and workers are gradually matched to better jobs. However, better job offers become less frequent for workers in a high quality match. For middle-aged and old workers the longer search history plays a dominant role. The standard deviation of match qualities increases. This occurs because workers are differently successful in finding good job offers and career paths diverge. Some workers have obtained many good job offers and are employed in a high productivity match at a high wage. At the same time, there are workers who flow from unemployment to employment for a low productivity match and a low wage. Workers reduce their search effort when they approach the retirement age and move therefore more slowly to higher productivity matches. This is reflected in the sharp increase in the standard deviation of this age group.

Figure 12 shows the age profile of the unemployment rate. It is decreasing strongly for young workers, since workers are initially unemployed and gradually matched to their first jobs.

## 5 Discussion

The age-inequality profile of wages is U-shaped if the bargaining power of workers is sufficiently high. If the bargaining power of workers is too low, the standard deviation of wages sharply decreases for old workers (see Figures 13 and 14). The bargaining power parameter has an effect on the age-inequality profile of wages through the worker's reservation wage. When  $\gamma$  is too low, young workers accept wages far below the match productivity

as their option value of on-the-job search is high. The shorter the time until retirement, the lower is the option value of on-the-job search. Older workers therefore demand higher wages. This increases the lowest bound of the conditional wage distribution given the match productivity. Hence, the standard deviation of wages decreases for workers close to retirement. When the bargaining power parameter is sufficiently large and the match quality is relatively high, the decreasing time horizon has the opposite effect on wages. Old workers accept lower wages since the probability of obtaining a better job offer by waiting decreases.

Figures 8 and 15 compare the age-wage profiles of the model economy with the empirical one. The age-wage profile in the US economy is hump-shaped.<sup>8</sup> Average wages increase with age for young and middle-aged workers. They decrease with age a few years before retirement. The worker's bargaining power must be sufficiently high such that the present model reproduces a hump-shaped age-wage profile. Because workers are gradually matched to better jobs, the average match quality and the average wage in the model economy increase with age. It increases at a decreasing rate because job offers from higher quality matches become less probable the higher the productivity of a match. All workers recruited out of unemployment who have not obtained any outside offer, have the same distribution of match productivities with a low average match quality independent of age. Because the search effort decreases with age, an increasing fraction of the workers in low quality matches does not move to higher quality matches. As there are permanent flows from unemployment to employment, the average match quality decreases some years prior to retirement. When the worker's bargaining power  $\gamma$  is high, the age-wage profile is similar to the age-match productivity profile and depicts the empirically observed hump-shaped age-wage profile. When  $\gamma$  is low, the above explained increase of the reservation wage has a positive effect on the average wage prior to retirement.

When the bargaining power parameter  $\gamma$  is chosen to match the empirically supported hump-shaped age-wage profile and the U-shape of the age-inequality profile of wages, it must be rather high (roughly 0.7) in this model. This is in contrast to Cahuc, Postel-Vinay, and Robin (2006) who find for French data that  $\gamma$  lies between 0 and 0.35. An exception is the high value of  $\gamma = 0.98$  for high skilled workers in the construction sector. Bagger, Fontaine, Postel-Vinay, and Robin (2011) explore the importance of human capital

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<sup>8</sup>A concave age-wage profile can be found in several empirical studies including Kambourov and Manovskii (2009) and Mincer (1974).

accumulation and labor market competition for life cycle wage dynamics in a bargaining framework similar to Cahuc, Postel-Vinay, and Robin (2006). They find in their analysis of Danish data that the bargaining power  $\gamma$  lies between 0.2475 and 0.4141 and declines with education. In both papers, workers have an infinite working life. The present paper provides a different interpretation of the bargaining power parameter. It contains information on the relative importance of the option value of on-the-job search over the life cycle.

## 6 Conclusions

I consider a life cycle model of labor market search with strategic wage bargaining, counteroffers, match heterogeneity and endogenous search effort. I show that the model can reproduce the U-shape of the age-inequality profile of wages if the bargaining power of workers is sufficiently high. Furthermore, the present model captures the shapes of the empirically observed age profiles of average wages, the unemployment to employment transition rate, and the employment to employment transition rate. The shape of the age-inequality profile of wages is mainly driven by the age profile of reservation wages, by transitions into employment, and transitions between employers. The optimal search effort of employed workers depends on the worker's time horizon before retirement, the current wage, and the quality of the firm-worker match. Furthermore, the probability of meeting an outside firm with a higher match quality decreases in the quality of the current match. This leads to frequent employment to employment transitions of young workers, a moderate employment to employment transition rate of middle aged workers, and a sharp decrease in the employment to employment transition rate of workers close to retirement. The bargaining power parameter plays an important role in the model because the option value of on-the-job search decreases when the time horizon before retirement shortens. A low bargaining power makes young workers accept a wage far below the productivity of the firm-worker match. Since the option value of on-the-job search is low for workers close to retirement, the reservation wage increases for old workers. This leads to a decline in the standard deviation of wages for old workers when the workers' bargaining power is too low.

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# APPENDIX

## A Estimation

Table 4: Regressors

| <b>Variable</b>                        | <b>Description</b>   |
|--|--|
| Major occupations (occ14)              | 1 Executive, Administrative, and Managerial<br>2 Professional Speciality<br>3 Technicians and Related Support<br>4 Sales<br>5 Administrative Support , Including Clerical<br>6 Private Household Services<br>7 Protective Services<br>8 Services, except Household and Protective<br>9 Farming, Forestry, and Fishing<br>10 Precision Production, Craft, and Repair<br>11 Machine Operators, Assemblers, and Inspectors<br>12 Transportation and Material Moving<br>13 Handlers, Equipment Cleaners, Helpers, and Laborers |
| Disability that limits work (disabled) | 0 not disabled<br>1 disabled   |
| Census Region (region)                 | 1 New England<br>2 Middle Atlantic<br>3 E. North Central<br>4 W. North Central<br>5 South Atlantic<br>6 E. South Central<br>7 W. South Central<br>8 Mountain<br>9 Pacific  |
| Marital Status (ms)                    | 0 Never Married<br>1 Married, Widowed, Divorced, or Separated  |
| Weekly hours (hours)                   | Weekly hours in dominant job   |

Table 5: Estimation results

| Variable               | Coefficient         | (Robust Std. Err.) |
|------------------------|---------------------|--------------------|
| 1b.occ14               | 0.000               | (0.000)            |
| 2.occ14                | -0.006              | (0.048)            |
| 3.occ14                | -0.050              | (0.046)            |
| 4.occ14                | -0.087**            | (0.031)            |
| 5.occ14                | -0.082*             | (0.032)            |
| 6.occ14                | -0.666**            | (0.236)            |
| 7.occ14                | -0.127*             | (0.057)            |
| 8.occ14                | -0.184**            | (0.033)            |
| 9.occ14                | -0.280**            | (0.048)            |
| 10.occ14               | -0.051 <sup>†</sup> | (0.028)            |
| 11.occ14               | -0.068*             | (0.030)            |
| 12.occ14               | -0.074*             | (0.036)            |
| 13.occ14               | -0.110**            | (0.030)            |
| 0b.disabled            | 0.000               | (0.000)            |
| 1.disabled             | -0.081**            | (0.022)            |
| 1b.region              | 0.000               | (0.000)            |
| 2.region               | 0.090               | (0.099)            |
| 3.region               | 0.193               | (0.131)            |
| 4.region               | 0.013               | (0.137)            |
| 5.region               | 0.083               | (0.108)            |
| 6.region               | 0.378**             | (0.135)            |
| 7.region               | 0.052               | (0.107)            |
| 8.region               | 0.165               | (0.130)            |
| 9.region               | 0.213               | (0.133)            |
| 0b.ms2                 | 0.000               | (0.000)            |
| 1.ms2                  | 0.094**             | (0.024)            |
| hours                  | 0.017**             | (0.001)            |
| Intercept              | 6.617**             | (0.102)            |
| <hr/>                  |                     |                    |
| Observations           | 180,848             |                    |
| Groups                 | 8,422               |                    |
| R <sup>2</sup> within  | 0.077               |                    |
| R <sup>2</sup> between | 0.356               |                    |
| R <sup>2</sup> overall | 0.244               |                    |
| F (72,8421)            | 46.028              |                    |

A <sup>†</sup> / \* / \*\* next to the coefficient indicates significance at the 10/5/1% level.

## B Simulation details

Let  $\delta_k$  denote the age dependent job destruction rate which is given by the empirical smoothed EU rate. Unemployed workers in the model experience a transition out of the labor market at rate  $\eta_k$  given by the empirical smoothed UN rate. Employed workers leave the labor market at rate  $\zeta_k$  given by the empirical smoothed EN rate. Transitions from non-participation to unemployment (employment) occur at rate  $\mu_k$  ( $\nu_k$ ) given by the empirical smoothed NU (NE) rate. Let  $l(k)$  be the mass of workers aged  $k$  who participate and  $n(k)$  be the mass of workers who do not participate in the labor market.

### B.1 Value functions

A worker who does not participate in the labor market obtains at least his value of unemployment. Otherwise she would search for a job. I assume that the value of being not in the labor market makes the worker indifferent between searching for a job and not searching. I therefore set the value of non-participation equal to the value of unemployment.<sup>9</sup> The value of unemployment becomes

$$\begin{aligned} \mathcal{U}(k) = \max_{e \geq 0} \Big\{ & b_U - c(e) + \beta \Big[ \mathcal{U}(k') \\ & + (1 - \delta_k)(1 - \xi_k)e\lambda\gamma \sum_{j=1}^n [\mathcal{W}(k', a_j, a_j) - \mathcal{U}(k')] p_j \Big] \Big\}. \end{aligned} \quad (\text{B.1})$$

The optimal search effort of an unemployed worker aged  $k$ ,  $e_U(k)$ , is the solution to the first order condition (FOC) of the maximization problem

$$c'[e_U(k)] = \beta(1 - \delta_k)(1 - \xi_k)\lambda\gamma \sum_{j=1}^n [\mathcal{W}(k', a_j, a_j) - \mathcal{U}(k')] p_j. \quad (\text{B.2})$$

The value of a job to a worker of age  $k < K - 1$  earning wage  $w$  in a match with productivity

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<sup>9</sup>Setting the value of non-participation equal to the value of unemployment plus a constant does not impact the results.

$a_i$  is derived as:

$$\begin{aligned}
\mathcal{W}(k, w, a_i) = \max_{e \geq 0} & \left\{ w - c(e) + \beta(1 - \xi_k) \left[ \delta_k \mathcal{U}(k') + (1 - \delta_k) \left[ \right. \right. \right. \\
& \left. \left( 1 - e\lambda[1 - P_{q(k', w, a_i)-1}] \right) \max \left\{ \mathcal{W}(k', w, a_i), \mathcal{U}(k') + \gamma[\mathcal{W}(k', a_i, a_i) - \mathcal{U}(k')] \right\} \right. \\
& + e\lambda \sum_{j=q(k', w, a_i)}^i \left( \mathcal{W}(k', a_j, a_j) + \gamma[\mathcal{W}(k', a_i, a_i) - \mathcal{W}(k', a_j, a_j)] \right) p_j \\
& \left. \left. \left. + e\lambda \sum_{j=i+1}^n \left( \mathcal{W}(k', a_i, a_i) + \gamma[\mathcal{W}(k', a_j, a_j) - \mathcal{W}(k', a_i, a_i)] \right) p_j \right] \right] + \beta \xi_k \mathcal{U}(k') \right\}.
\end{aligned} \tag{B.3}$$

The FOC that determines an employed worker's search effort is

$$\begin{aligned}
c'[e_W(k, w, a_i)] = & \beta(1 - \delta_k)(1 - \xi_k)\lambda \left( \sum_{j=q(k', w, a_i)}^i \left[ (1 - \gamma)\mathcal{W}(k', a_j, a_j) + \gamma\mathcal{W}(k', a_i, a_i) \right] p_j \right. \\
& + \sum_{j=i+1}^n \left[ (1 - \gamma)\mathcal{W}(k', a_i, a_i) + \gamma\mathcal{W}(k', a_j, a_j) \right] p_j \\
& \left. - (1 - P_{q(k', w, a_i)-1}) \max \left\{ \mathcal{W}(k', w, a_i), \mathcal{U}(k') + \gamma[\mathcal{W}(k', a_i, a_i) - \mathcal{U}(k')] \right\} \right).
\end{aligned} \tag{B.4}$$

## B.2 Transition rates and wage distribution

The wage distribution is discretized for the model simulation.  $u(k)$ ,  $n(k)$ ,  $g(k, w_s, a_i)$ ,  $g(k, a_i)$ , and  $G(w_s|k, a_i)$  with  $s = 1, \dots, S$  and  $w_{s-1} < w_s$  are determined as follows:<sup>10</sup>

- $n(1)$ ,  $l(1)$ , and  $u(1)$  are given
- $g(2, a_i) = [e_U(1)\lambda u(1) + v_1 n(1)] p_i$
- 

$$G(w_s|2, a_i) = \begin{cases} 1 & \text{if } w \geq \phi_0(2, a_i) \\ 0 & \text{if } w < \phi_0(2, a_i) \end{cases}$$

<sup>10</sup>I obtain the wage distribution of workers aged 18 ( $k = 1$ ) by running a simulation covering 13 months ahead of the main simulation.

•

$$g(2, w_s, a_i) = \begin{cases} g(2, a_i)G(w_1|2, a_i) & \text{if } s = 1 \\ g(2, a_i)[G(w_s|2, a_i) - G(w_{s-1}|2, a_i)] & \text{if } s > 1 \end{cases}$$

•  $u(2) = (1 - \lambda e_U(1) - \eta_1)u(1) + \mu_1 n(1)$

•  $n(2) = (1 - \mu_1 - v_1)n(1) + \eta_1 u(1)$

For  $k \geq 2$  the following steps are repeated:

1.

$$\begin{aligned} g(k+1, a_i) &= [e_U(k)\lambda u(k) + v_k n(k)] p_i \\ &+ (1 - \delta_k - \zeta_k) \lambda p_i \sum_{j=1}^{i-1} \sum_{s=1}^S e_W(k, w_s, a_j) g(k, w_s, a_j) \\ &+ (1 - \delta_k - \zeta_k) \sum_{s=1}^S [1 - e_W(k, w_s, a_i) \lambda (1 - P_i)] g(k, w_s, a_i) \end{aligned}$$

2.

$$\begin{aligned} G(w_s|k+1, a_i) &= I_{w_s \geq \phi_0(k+1, a_i)} \left\{ [e_U(k)\lambda u(k) + v_k n(k)] p_i \right. \\ &+ (1 - \delta_k - \zeta_k) \lambda p_i \sum_{j=1}^{q(k+1, w_s, a_i)-2} \sum_{r=1}^S e_W(k, w_r, a_j) g(k, w_r, a_j) \\ &+ (1 - \delta_k - \zeta_k) \sum_{r=1}^S [1 - e_W(k, w_r, a_i) \lambda (1 - P_{q(k+1, w_s, a_i)-1})] g(k, w_r, a_i) \left. \right\} \\ &/ g(k+1, a_i). \end{aligned}$$

3.

$$g(k+1, w_s, a_i) = \begin{cases} g(k+1, a_i)G(w_1|k+1, a_i) & \text{if } s = 1 \\ g(k+1, a_i)[G(w_s|k+1, a_i) - G(w_{s-1}|k+1, a_i)] & \text{if } s > 1 \end{cases}$$

4.  $u(k+1) = (1 - \lambda e_U(k) - \eta_k)u(k) + \mu_k n(k) + \delta_k \sum_{j=1}^n g(k, a_j)$

5.  $n(k+1) = (1 - \mu_k - v_k)n(k) + \eta_k u(k) + \zeta_k \sum_{j=1}^n g(k, a_j)$

## C Figures

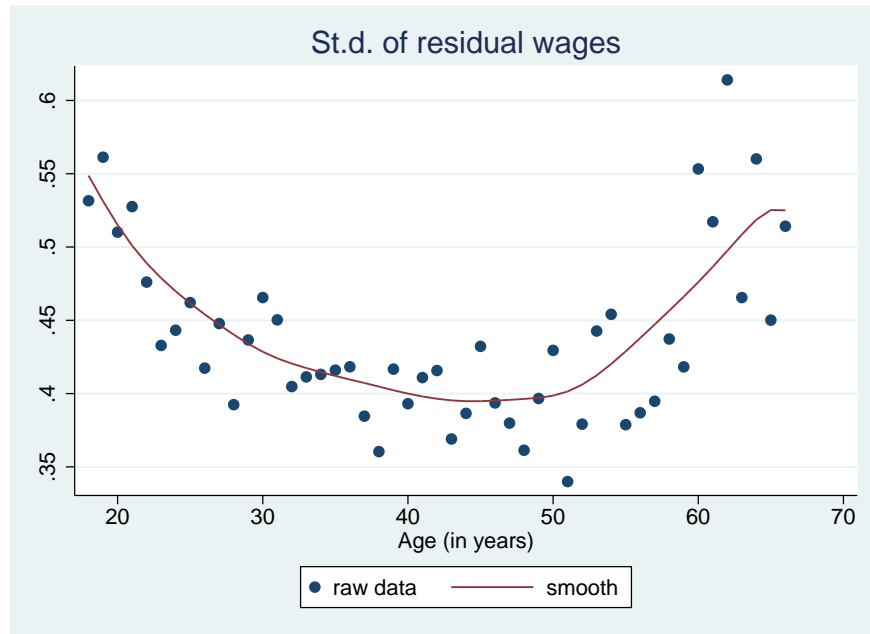


Figure 1: Age-inequality profile of residual log wages

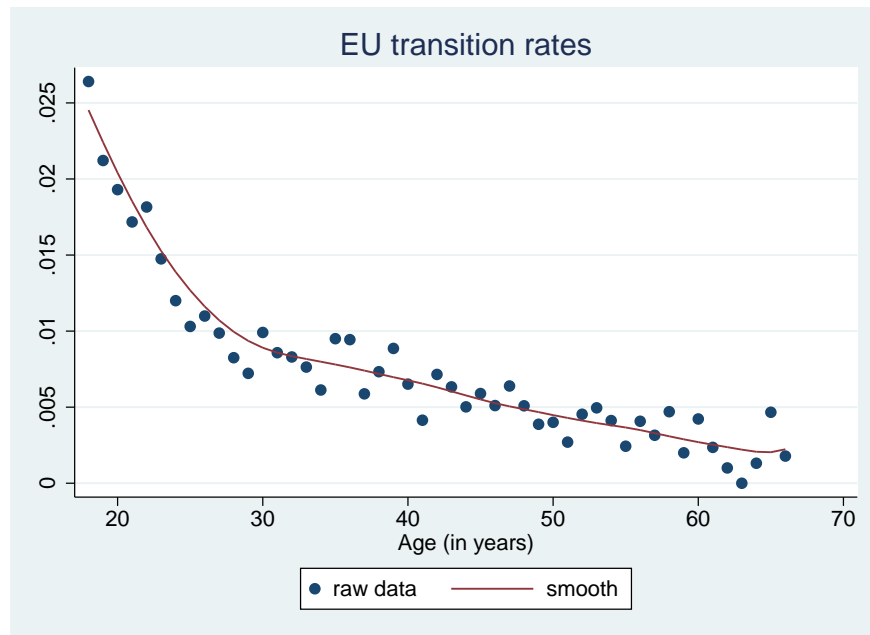


Figure 2: Life cycle profile of the job destruction rate

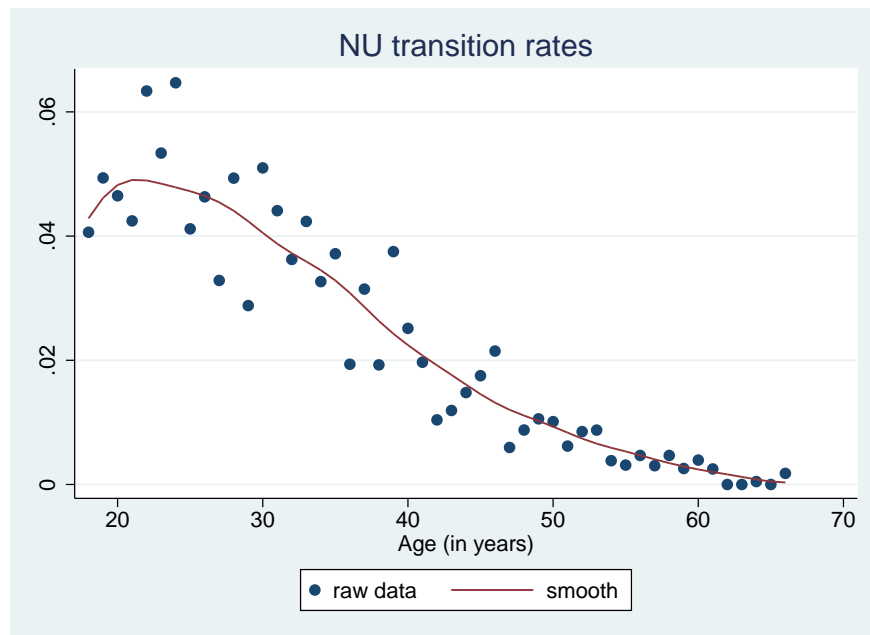


Figure 3: NU rate

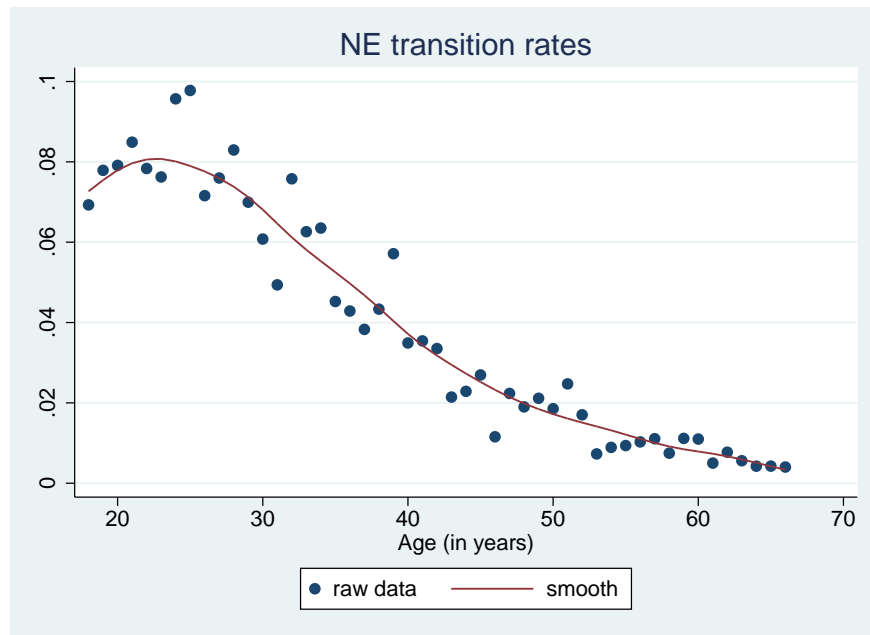


Figure 4: NE rate

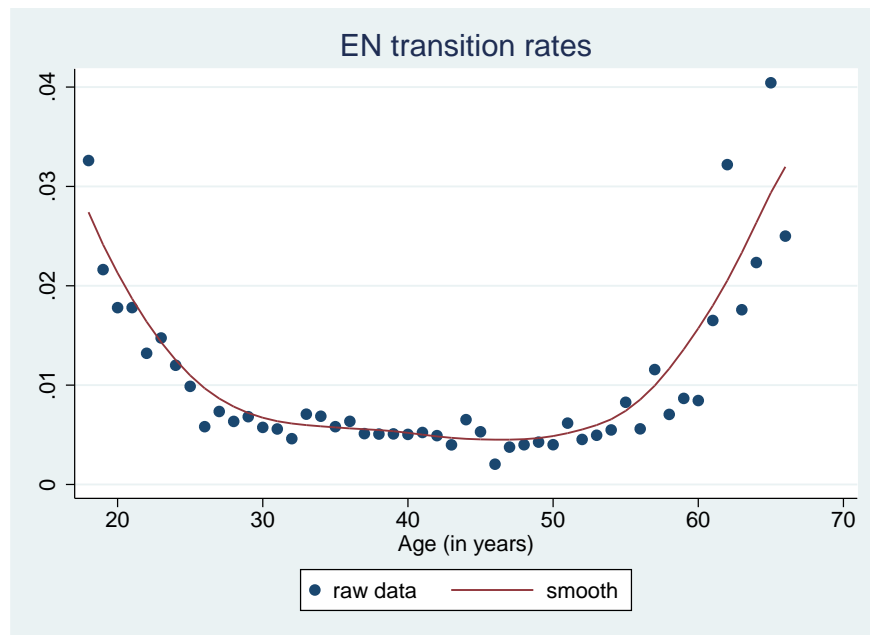


Figure 5: EN rate

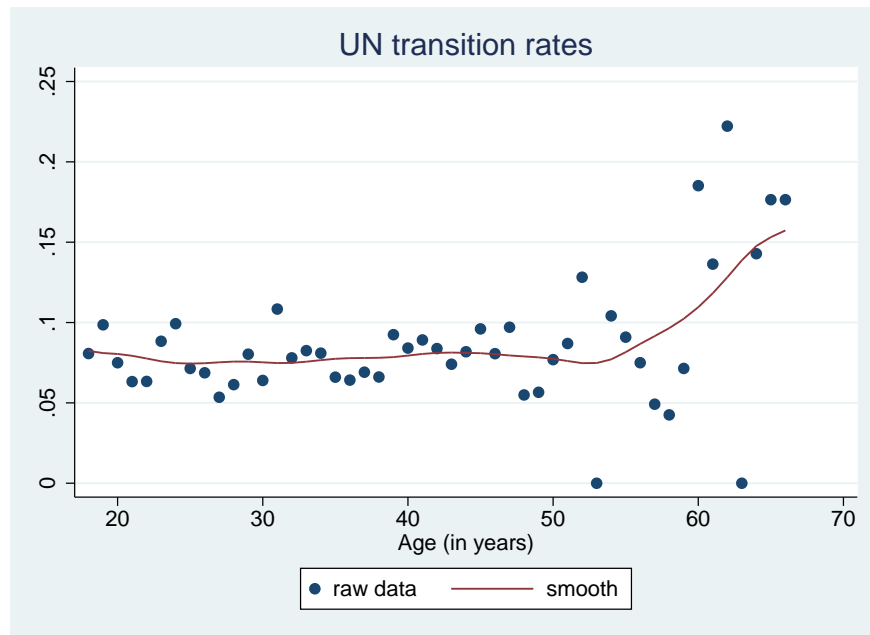


Figure 6: UN rate

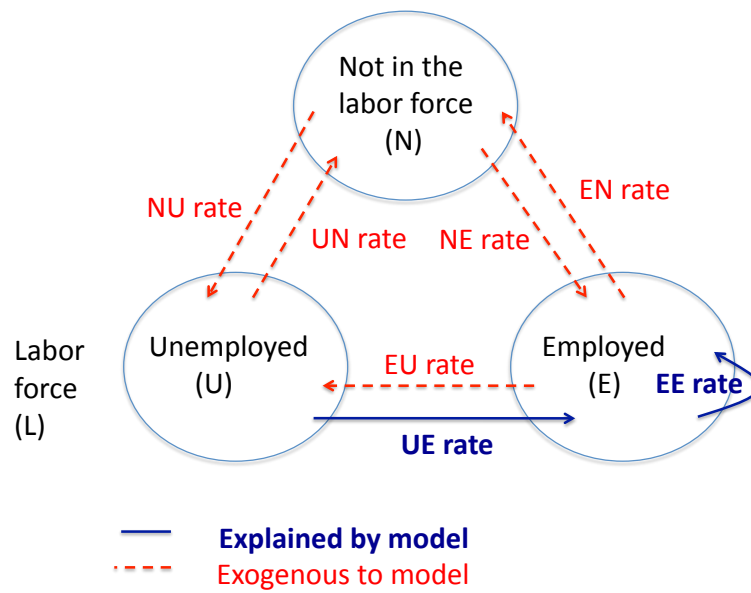


Figure 7: Labor market transitions

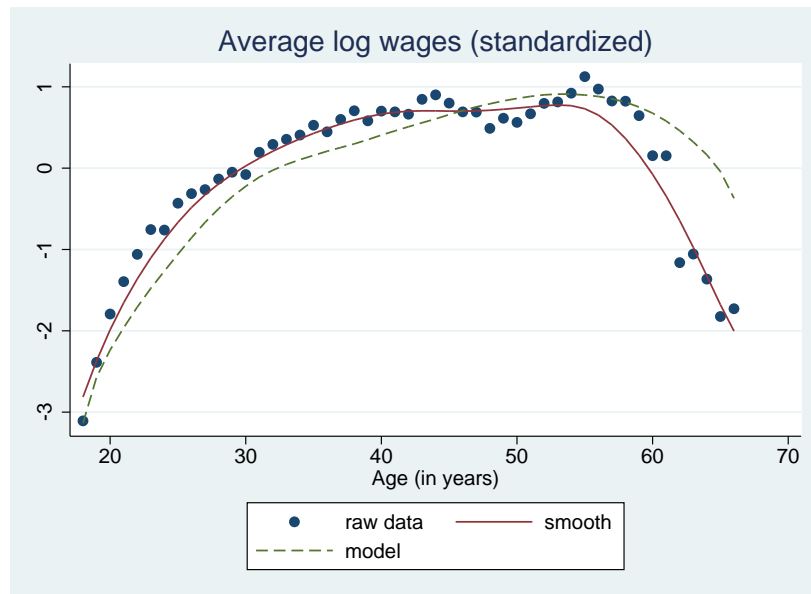


Figure 8: The age profiles of average log wages are standardized for comparability between model and data. The standardized age-specific average wage is derived by dividing the difference between the age-specific average wage and its mean by its standard deviation.

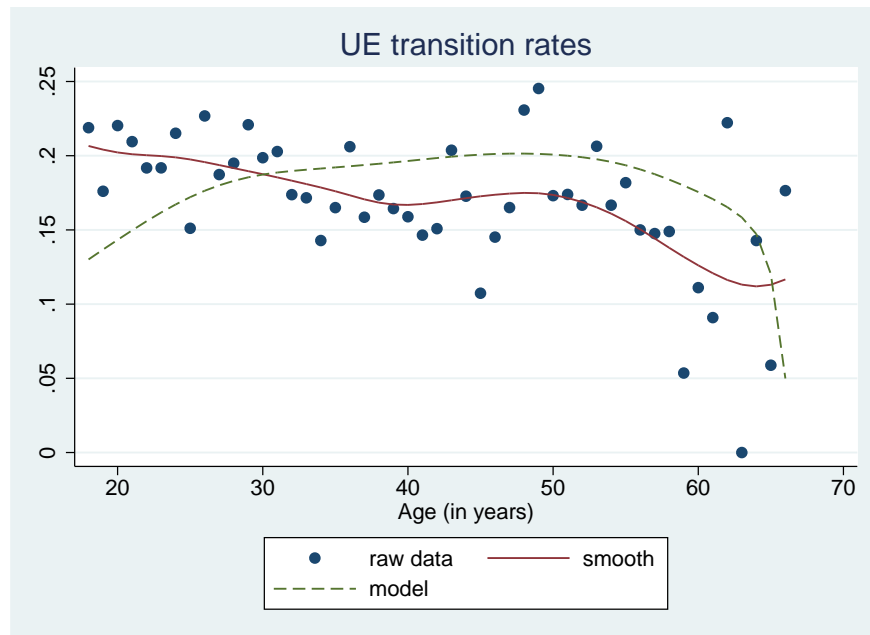


Figure 9: Average unemployment to employment transition rates

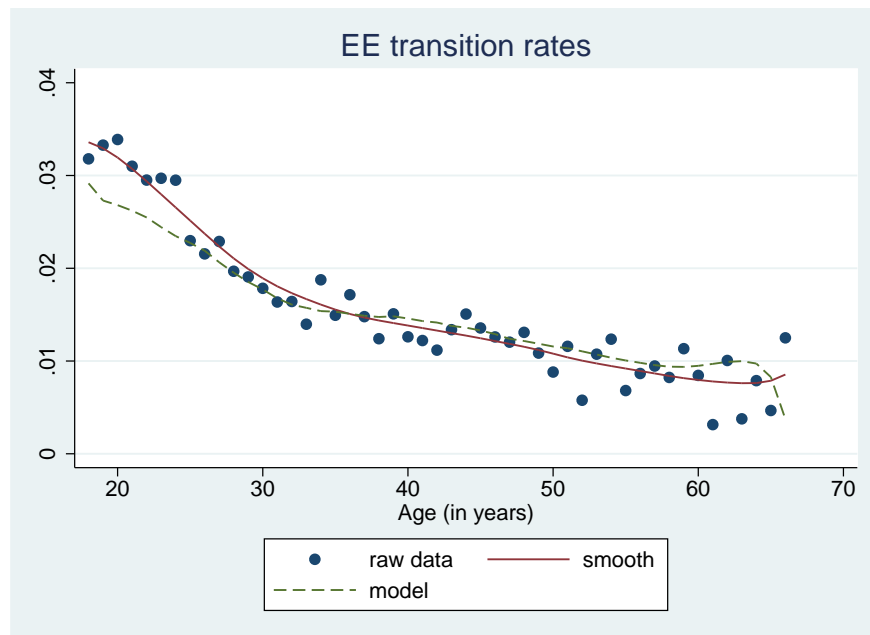


Figure 10: Average employment to employment transition rates

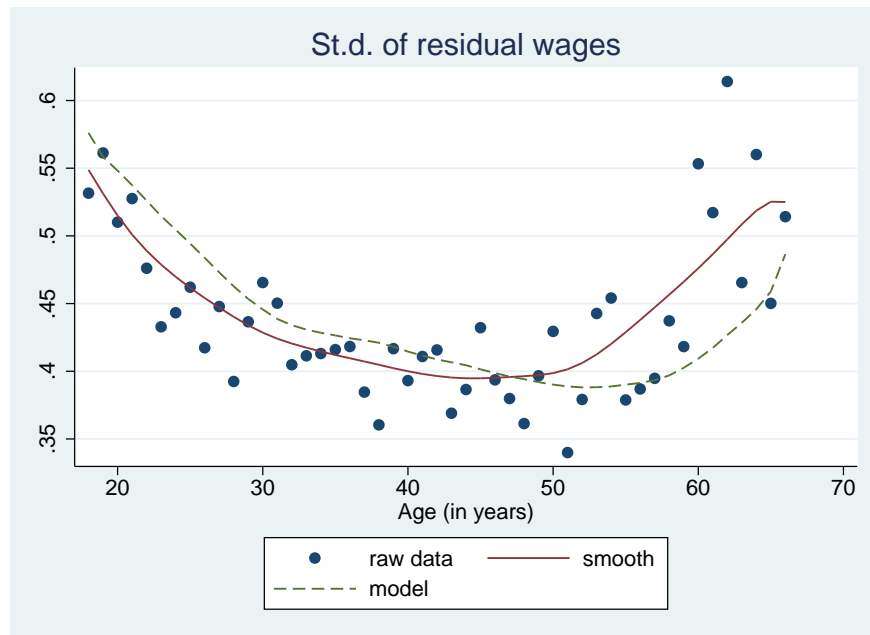


Figure 11: Wage dispersion

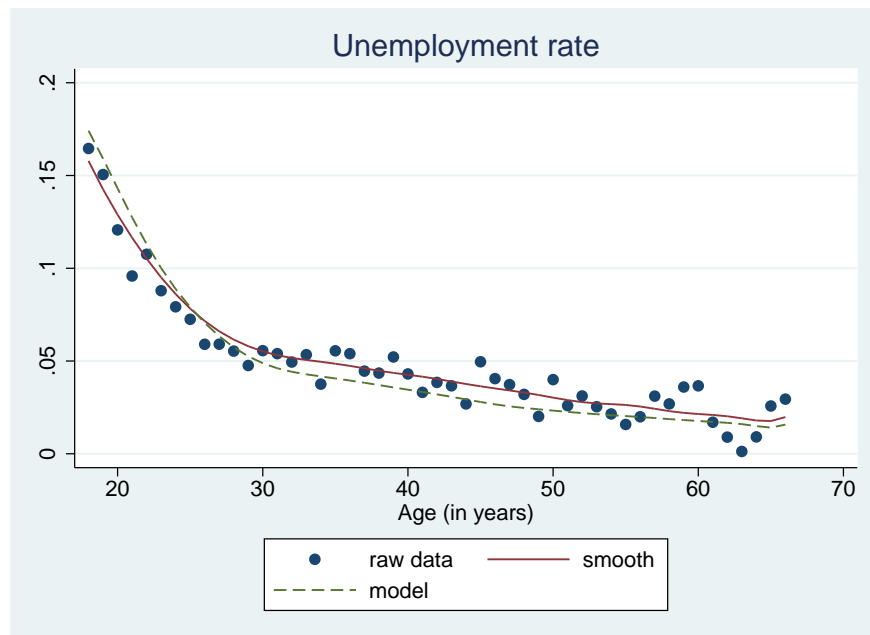


Figure 12: Unemployment rates



Figure 13: Dispersion of wages and match qualities; estimated  $\gamma = 0.7172$



Figure 14: Calibrated model if  $\gamma = 0.5$



Figure 15: Calibrated model if  $\gamma = 0.5$