Simultaneous Search, On-the-Job Search, and the Shape of the Wage Distribution*

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Abstract

I present an equilibrium search model of the labor market in which workers can search for a better match while employed. An important novelty compared to existing on-the-job search models is that I allow workers to send multiple applications and to communicate their current wage to the firm offering them a new job. Based on this information firms make a wage offer to which they commit. I show that wage dispersion remains to be an equilibrium outcome, because firms take into account potential competition from other firms for the same job candidate. The equilibrium wage density has continuous support and a unique interior mode, even in a market with identical workers and firms. High wage levels cannot be reached directly from unemployment, but require several job-to-job transitions. The speed with which workers climb the wage ladder is stochastic. By calibrating the model I show that changes in the level of unemployment benefits have a larger effect on the job offer arrival rate of the unemployed than of the employed. The opposite holds when considering changes in the job destruction rate.

Keywords: simultaneous search, on-the-job search, wage dispersion, labor market frictions
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1 Introduction

Even within narrowly defined occupations in narrowly defined industries, there exists a lot of wage dispersion under workers with similar characteristics (see e.g. the references in chapter 1 of Mortensen,

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2003, for empirical evidence). Two seminal contributions that explain this are Burdett and Judd (1983) and Burdett and Mortensen (1998).[1] In both papers, wage dispersion arises because firms realize that there is a chance that they compete with other firms for their candidate but they do not know exactly with how many firms and with which firms. In the Burdett-Judd model this is because the number of job offers that a worker receives is a random variable and in Burdett-Mortensen this uncertainty arises because some candidates are already employed and their current wage can be considered to be the offer that must be beaten. Both papers derive a continuous wage distribution but unfortunately, the density is increasing while in the data it is typically hump-shaped with a long right tail. In this paper, I show that by combining elements from both these models, a hump-shaped wage distribution can be derived.

Specifically, I construct a model of simultaneous search in which workers can search on-the-job. Like Pissarides (2000) and Mortensen (2000), I assume that each firm has exactly one position, that is either vacant or filled. An important new element in my model is that I increase the firms' strategy space in two ways: (i) I allow firms to choose a candidate from the pool of applicants based on their previous employment state and (ii) I allow firms to condition their wage offer on the previous wage of their candidate if she had one. The motivation for this setup is the following. In general it is very easy for firms to learn the current employment state of an applicant, for example from her curriculum vitae or from the references that she provided. It is in the firm's interest to use this information when making invitations for a job interview. *Ceteris paribus*, unemployed workers have worse outside options and are therefore cheaper than workers that have a job already. Ideally, firms also would like to know the wages of their employed applicants, but since workers and references do not report this it seems impossible to obtain this information at this stage of the recruitment process.[2]

However, as soon as a suitable candidate has been found, the first question in the final interview before making an offer usually is: "What is your current wage?". In fact, it is in the interest of firms to ask this question. In the Burdett-Mortensen model some contacts do not result in a match, because a firm offers too little to a worker who was earning a high wage already. But, since all wages in equilibrium are strictly lower than the productivity of the match, a positive surplus could have been shared, if only the firm had known how much the worker was earning in her current job. Clearly, workers earning high wages suffer the most from this lack of communication and are happy to announce their salary. I assume that all workers truthfully reveal how much they earn. After all, if the firm is not sure whether the worker tells the truth, it can ask for previous employment contracts.

In the Burdett-Mortensen model, where one worker and one firm meet at a time, revelation of

[1] Other examples include Albrecht and Axell (1984), Lang (1991), Acemoglu and Shimer (2000), and Postel-Vinay and Robin (2002). In fact, Burdett and Judd (1983) develop a consumer search model to explain price dispersion. Their model can however be adapted to the labor market without changing its fundamental properties, see e.g. Gautier and Moraga-González (2005). I stick to labor market terminology to keep the discussion coherent.

[2] Analyzing a model in which firms can observe the wages of their applicants before they have to select one is very interesting from a theoretical point of view, but also technically difficult. In a model with continuous support of the wage distribution, this would create an infinite number of worker types, implying that firms need to develop a selection strategy for each of the infinitely many different pools of applicants that they can have. This could result in endogenous segmentation of the labor market, where firms are indifferent between all workers in a segment, but only offer the job to worker from an expensive segment if no cheaper applicants show up.

the wages would destroy wage dispersion. Firms would offer a wage that is only marginally higher than the worker's current salary and the Diamond (1971) paradox with its degenerate wage distribution would prevail again. However, in a world of simultaneous search this is not the case. Firms take into account the potential competition of other firms for the same worker and continue to play a mixed strategy. I show that my model leads to a wage density that is similar to what typically is found in data. It has continuous support, a unique interior mode, and a long right tail, even if all agents are fully homogeneous. This is an important improvement compared to the Burdett-Mortensen model, which generates a strictly upward sloping earnings density. Most papers, like Bowlus et al. (1995), van den Berg and Ridder (1998), Bontemps et al. (1999, 2000), and Postel-Vinay and Robin (2002), have used heterogeneity on the firm and/or worker side to obtain a better fit of the data. Although my model can easily be extended to include such heterogeneity, it does not require it to get the right shape of the wage distribution. The model is therefore suitable for a careful empirical assessment of the question which fraction of wage dispersion can be attributed to simultaneous search, on-the-job search, and productivity differences respectively.

Several other papers are related to what I do here. Carrillo-Tudela (2004) also describes a model with on-the-job search in which firms can observe the employment state of the workers. Firms can condition their wage offers on this state but not on the actual wage level. This results in a degenerate wage distribution for the unemployed and a upward sloping wage density, like in Burdett-Mortensen, for the employed. As argued above, allowing firms to condition on the current wage as well seems a realistic and important extension. A second difference concerns the matching technology. In Carrillo-Tudela (2004), workers get job offers from firms according to a Poisson process, i.e. one offer at a time. I use an urn-ball matching technology based on micro-foundations, in which workers can get multiple job offers.[3] The aggregate matching function is determined by the interplay between two coordination frictions: (i) workers do not know where other workers send their job applications and (ii) firms do not know which workers other firms make employment offers to.

Delacroix and Shi (2006) study on-the-job search in a directed search setting. They find a wage distribution with a finite number of mass points as support. Together these mass points form a wage ladder and workers choose to only apply to firms that offer a wage that is one rung higher than their current wage level. My model generates a wage distribution that has a similar ladder structure. Not all wage levels can be reached directly from unemployment and it requires several job-to-job transitions to earn a really high wage. This is fundamental difference compared to models based on the Burdett-Mortensen framework, where even the highest wage in the economy can be obtained directly after an unemployment spell. Unlike the model by Delacroix and Shi (2006) however, my model allows for variation in the speed with which workers climb the ladder. Some workers experience larger wage increases between two jobs than others.

A few authors also obtain a hump-shaped wage density. For example, Mortensen (2000) creates

[3]In current work, it has become standard to analyze a framework in which workers can send out simultaneous job applications, see Albrecht et al. (2003, 2004, 2006), Shimer (2004), Gautier and Moraga-González (2005), Gautier and Wolthoff (2006), Chade and Smith (2006), Galenianos and Kircher (2007), Kircher (2007), and Gautier et al. (2007).

endogenous productivity differences across jobs by introducing match specific investments by firms. Burdett et al. (2008) extend the Burdett-Mortensen framework by allowing workers to accumulate human capital while employed. They show that this results in a wage distribution that has a long Pareto tail. My model is simpler in this respect. The wage dispersion exclusively follows from a trade-off in the wage setting mechanism. Firms want to minimize wage payments, but realize that they can only hire the worker if their offer beats both the current employer of the worker and other recruiting firms.

This paper is organized as follows. Section 2 describes the setting of the model and section 3 solves for the equilibrium. In section 4 I characterize the earnings density and discuss its properties. Section 5 concludes.

2 Model

2.1 Setting

I consider a labor market with a continuum of identical firms and a continuum of identical workers. Time is discrete and I focus on the steady state. Workers can supply one indivisible unit of labor. Hence, each worker is either employed at one of the firms or unemployed. Likewise, each firm has one job, which can be in two states: filled by a worker and producing, or vacant. I normalize the measure of workers to 1 and denote the fractions of employed and unemployed workers by $1-u$ and u respectively. The measure of firms with vacancies is denoted by v and is endogenously determined by free entry.

A worker who is employed in a given period gets a payoff that is equal to her wage w. On the other hand, unemployed workers have a payoff equal to h, consisting of unemployment benefits, home production, and the value of leisure. A firm that gives employment to a worker produces an output y, but has to pay the worker's wage w. Hence, the firm's payoff equals $y-w$. Firms with a vacancy do not produce, but pay a vacancy cost $k>0$. Their payoff therefore equals $-k$.

Firms maximize the expected discounted future value of output minus capital and wage costs, while workers maximize the expected discounted value (hereafter, 'value') of future wage payments. All agents discount future payoffs at rate $1/(1+r)$ and are infinitely-lived and risk-neutral. As is common in the search literature, I introduce frictions in the market by considering equilibrium strategies that are symmetric and anonymous. This implies that all workers use the same application strategy, which they cannot condition on the firms' identities. Similarly, all firms use identical strategies, which cannot be based on the workers' identities.

Firms move first by deciding whether they want to enter the market. A firm that enters incurs the vacancy cost k as long as it is unmatched. Next, workers search for new jobs by applying to these vacancies. A worker applies to jobs at the beginning of a period, but only learns whether she is accepted or not at the end of the period. In such a setting, searching non-sequentially is optimal (see Morgan and Manning, 1985). Sending multiple applications can have two positive effects. First, it reduces the risk of not finding a new job. The second positive effect requires wage dispersion. If not all wage offers are the same, sending several applications increases the chance of getting a juicy offer. In case of wage dispersion, employed workers have an incentive to search as well, because they might be able to find a better paying job.

In each period, workers apply to all vacancies that they observe. The number of observed vacancies is however stochastic. It follows a Poisson distribution with mean $\alpha_U > 0$ for unemployed workers and $\alpha_E > 0$ for employed workers.[4] I allow for different 'vacancy observation rates' on and off the job to keep the model as general as possible. Analyzing the case with fully homogeneous workers is however straightforward by imposing $\alpha_U = \alpha_E$.

A firm with a vacancy observes the employment state of each applicant. Based on this, it selects one candidate. Hence, the firm can choose whether it wants to contact an unemployed or an employed worker. Let λ denote the probability with which the firm selects an unemployed worker. The choice is trivial in case the firm has only one type of applicants, but if both types show up, the firm may use a pure strategy, i.e. $\lambda \in \{0,1\}$, or mix between both types of workers, $\lambda \in (0,1)$. Note that the firm can observe the employment state, but cannot discriminate further, implying that within the group of workers with the same state, it selects a candidate randomly. Other applications are returned as rejections.

The firm contacts the candidate and during this contact it learns her current wage x. Conditional on this, it makes her a wage offer w, to which it commits. Let F_x be the distribution of wage offers to workers currently earning a wage x, with corresponding support $\mathscr{F}_x$. The distribution of wage offers to unemployed workers and its support are denoted by F_h and $\mathscr{F}_h$ respectively. The distributions F_x and F_h are equilibrium objects which are derived in section 3.1. They are common knowledge, but in case firms play a mixed strategy, workers do not know ex ante which wage a specific firm will offer. Firms commit to not counter outside offers received by the worker.

After learning the result of their applications, workers accept their best wage offer, as long as this gives a higher expected future payoff than remaining in the current job or state. All other wage offers are rejected. In line with literature, see e.g. Pissarides (2000), I assume that in each period a fraction $\delta \in (0,1)$ of the employed workers experiences an exogenous job destruction shock. The workers in question cannot search in that period and flow back into unemployment. Their former jobs become vacant.

Although unemployed workers technically do not earn a salary, I will in the remainder of this paper often refer to them as 'workers earning h' for reasons of convenience. I define a function $s(x) \in \{U,E\}$, which maps the 'wage' x into the employment state of the worker. Hence,

$$s(x) = \begin{cases} U & \text{if } x = h \\ E & \text{if } x > h. \end{cases}$$

I will often suppress the argument of s, to keep notation simple as simple as possible.

[4] Endogenizing search intensity, like in Kaas (2007) or Gautier et al. (2007), would be a nice extension of the model, but complicates the analysis a lot without affecting the main conclusions of this paper. Therefore, I consider $\alpha_U > 0$ and $\alpha_E > 0$ to be exogenously given.

The strategies of the workers and the firms together imply a steady state earnings distribution $G(w)$, representing the fraction of employed workers earning a wage lower than w. I denote the corresponding density by $g(w)$ and its support by $\mathscr{G}$. In some cases I will refer to both employed and unemployed workers. For this purpose, define $\mathscr{G}' = \mathscr{G} \cup h$. I characterize the earnings distribution in section 4, after describing the matching technology, the workers' and firms' strategies, and the market equilibrium.

2.2 Matching Technology

The urn-ball matching framework that I use here, has been analyzed many times before in the literature. The first ones to use this micro-foundation of the matching process were Butters (1977) and Hall (1977). Albrecht et al. (2003) and Albrecht et al. (2004) extend the model by allowing for simultaneous search. In their specification the number of applications is a exogenous, discrete and finite number, which leads to relatively complicated binomial probabilities. Kaas (2007) circumvents this problem by introducing a continuous parameter, which is the mean of a Poisson process that determines the actual number of applications. I follow this approach here.

In every period, all unemployed and all employed not hit by the job destruction shock observe a fraction of the vacancies. Unemployed workers observe each of the $\widehat{v}$ vacancies with probability $\frac{\alpha_U}{\widehat{v}}$, while employed workers workers observe each of them with probability $\frac{\alpha_E}{\widehat{v}}$, where $\widehat{v} \to \infty$, keeping the ratio of $\widehat{v}$ over the number of workers fixed to v. In order to keep notation simple, I assume that $\alpha_U \geq \alpha_E$. The observations are independent across workers and vacancies, implying that the actual number of applications that a worker of type $s \in \{U, E\}$ observes, follows a Poisson process with mean α_s. Workers apply to all vacancies that they observe. All firms are equally likely to receive applications, which means that the expected queue length, i.e. the expected number of applications per vacancy, is equal to the total number of applications sent out divided by the number of vacancies. I distinguish between applications from unemployed and from employed workers. So, let ϕ_s denote the expected queue length formed by type $s \in \{U, E\}$ applicants, then the following expressions hold:

$$\phi_U = \frac{u\alpha_U}{v}$$

and

$$\phi_E = \frac{(1-\delta)(1-u)\alpha_E}{v}.$$

Due to the infinite size of the labor market, the actual number of applicants of type s at a specific vacancy follows a Poisson distribution with mean ϕ_s. Moreover, the number of competitors of type s that a worker faces at a given firm follows a Poisson distribution with mean ϕ_s as well.

The candidate selection proceeds in two steps. The firm first selects a type (U, E) of worker and after that it selects a candidate within that type. Consider an unemployed worker who has applied to a firm. In order to get a job offer, two things must happen. First, the firm must decide that it will offer the job to an unemployed applicant and second the worker has to be selected from the firm's pool of applicants without a job. The firm will select an unemployed worker with probability 1 if no employed workers show up (probability $e^{-\phi_E}$) and with probability λ otherwise. Conditional on this decision the worker has a probability $\frac{1}{n+1}$ to be selected, where n is her number of competitors, i.e. other applicants of the same type. Therefore, the probability to be selected equals

$$\sum_{n=0}^{\infty} \frac{1}{n+1} \frac{e^{-\phi_s} \phi_s^n}{n!} = \frac{1}{\phi_s} \left(1 - e^{-\phi_s}\right).$$

Hence, the job offer probability for an application send by an unemployed worker equals

$$\psi_U = \left(e^{-\phi_E} + \lambda \left(1 - e^{-\phi_E}\right)\right) \frac{1}{\phi_U} \left(1 - e^{-\phi_U}\right).$$

In a similar way, I find that the probability that an application by an employed worker results in a match is given by

$$\psi_E = \left(e^{-\phi_U} + (1 - \lambda) \left(1 - e^{-\phi_U}\right)\right) \frac{1}{\phi_E} \left(1 - e^{-\phi_E}\right).$$

Given the number of applications that a worker sends, the number of wage offers that she receives follows a binomial distribution with success probability ψ_s.[5] Initially, the worker does not know how many applications she will observe. The probability that she observes exactly n is given by $e^{-\alpha_s} \frac{\alpha_s^n}{n!}$. Hence, the ex ante probability to get j job offers is equal to

$$\begin{aligned} \chi_s(j) &= \sum_{n \geq j} e^{-\alpha_s} \frac{\alpha_s^n}{n!} \begin{pmatrix} n \\ j \end{pmatrix} \psi_s^j (1 - \psi_s)^{n-j} \\ &= e^{-\alpha_s \psi_s} \frac{(\alpha_s \psi_s)^j}{j!}. \end{aligned} \tag{1}$$

Hence, the number of job offers follows a Poisson distribution with mean $\alpha_s \psi_s$. One can interpret $\alpha_s \psi_s$ as the job offer arrival rate with which employed and/or unemployed workers get wage offers, like in Burdett and Mortensen (1998). However, workers might now get multiple job offers simultaneously, since time is discrete. The exact number of job offers is stochastic. Some workers are lucky and get multiple job offers, while others are unfortunate and remain unmatched. In this sense, the model is close to the noisy search model of Burdett and Judd (1983).

2.3 Strategies and Payoffs

A worker takes the matching technology and the firms' strategies as given and decides whether she wants to accept or reject the (best) wage offer that she gets. She chooses the action that maximizes her expected discounted future payoff. This payoff depends on whether she is unemployed or employed. I construct a Bellman equation for each state. Let V_U denote the value of unemployment and $V_E(x)$ the value of being employed at wage $x \in \mathcal{G}$. The immediate payoff of an unemployed worker equals h. She observes vacancies at rate α_U, which can result in $j \in N$ job offers from the distribution F_h. She

[5] See Albrecht et al. (2006).

accepts the best wage offer, if she gets one, as long as the associated payoff $V_E(w)$ is higher than the payoff of remaining unemployed and rejects otherwise. Hence, the value of unemployment equals

$$V_U = h + \frac{1}{1+r}\left(\sum_{j=1}^{\infty} \chi_U(j) \int_{w\in\mathscr{F}_h} \max\{V_E(w), V_U\}\, dF_h^j(w) + \chi_U(0) V_U\right). \tag{2}$$

A similar expression holds for the value of employment. The immediate payoff is now equal to the worker's current wage x. If not hit by the job destruction shock, she sends $n \sim Poi(\alpha_E)$ applications which can result in $j \in \mathbb{N}$ job offers. Again, the worker accepts the (best) offer if it gives a higher payoff than rejecting it. Hence, $V_E(x)$ equals

$$V_E(x) = x + \frac{1}{1+r}\widetilde{V}_E(x), \tag{3}$$

where the continuation value $\widetilde{V}_E(x)$ equals

$$\begin{aligned} \widetilde{V}_E(x) &= (1-\delta)\sum_{j=1}^{\infty} \chi_E(j) \int_{w\in\mathscr{F}_x} \max\{V_E(w), V_E(x)\}\, dF_x^j(w) \\ &\quad + (1-\delta)\chi_E(0) V_E(x) + \delta V_U. \end{aligned} \tag{4}$$

Formally, the strategy of workers can be characterized by acceptance sets, consisting of the wage offers that they are willing to accept. A worker rejects all wage offers that are not part of her acceptance set. I simplify notation by conjecturing that workers follow a reservation wage strategy. A worker currently earning $x \in \mathscr{G}'$, accepts her best wage offer if it is higher than her reservation wage $w_R(x)$ and rejects it otherwise.[6] I show in section 3.2 that such a strategy is indeed optimal from the worker's point of view.[7]

Firms take the strategies of the workers and the other firms as given and choose (i) whether they want to enter the market, (ii) their selection probability λ and (iii) their wage offer distributions F_x, such that they maximize their expected discounted future payoff. Again, I construct two Bellman equations. Denote the firm's value of giving employment to a worker at wage w by $V_F(w)$ and the value of having a vacancy by V_V. A firm hiring a worker at wage w has an instant payoff of $\pi_w = y - w$. In the next period, the match terminates if a job destruction shock occurs (with probability δ) or if the worker moves to a better paying job (with endogenous probability $(1-\delta)\xi(w)$). The job opening at the firm becomes vacant again in that case. Otherwise, the firm continues to be matched. Hence, the value

[6] Workers that get an offer equal to their reservation wage are indifferent between accepting and rejecting the offer. As a tie-breaking rule I assume that workers always reject in this event of measure zero.

[7] In writing down the Bellman equation for employed workers, I implicitly assume that their labor market status is observed by the firms to which they apply before they obtain the wage payment by their current employer. This guarantees that workers with a very low wage do not want to quit their current job in order to have better chances in their search for a new job.

function $V_F(w)$ equals

$$V_F(w) = y - w + \frac{1}{1+r}\left((1-\delta)\,\xi(w)\,V_V + (1-\delta)\,(1-\xi(w))\,V_F(w) + \delta V_V\right). \tag{5}$$

A firm that has a vacancy does not produce, but has to pay the vacancy cost. So, its immediate payoff equals $-k$. Its continuation value depends on the candidate it selects and the wage offer it makes to this worker. Consider a firm with a vacancy that offers a wage w to an applicant of which it knows that she currently earns $x \in \mathscr{G}$'. Let $m_F(w|x)$ denote the firm's matching probability in this case. Then the firm's continuation value conditional on its wage offer equal

$$\widetilde{V}_V(w|x) = m_F(w|x)\,V_F(w) + (1 - m_F(w|x))\,V_V. \tag{6}$$

The firm faces a trade-off. Offering a higher wage increases the matching probability $m_F(w|x)$, since workers can compare offers. However, simultaneously it lowers the value $V_F(w)$ of the future match. Firms will offer wages such that they maximize equation (6). This determines distribution the wage offer distribution F_x. I denote the maximum value that firm can obtain by $\widetilde{V}_V(x)$.

A firm with both employed and unemployed applicants can choose to which type it wants to offer the job. If the firm selects an unemployed worker, its continuation value equals $\widetilde{V}_V(U) = \widetilde{V}_V(h)$. In case the firm chooses an employed worker, it is unsure about the payoff it will get, since the current wage of the worker is still unknown at the moment of selection. The continuation value therefore equals the expected value of $\widetilde{V}_V(x)$.

$$\widetilde{V}_V(E) = \int \widetilde{V}_V(x)\,dG(x).$$

The firms with both types of applicants, selects the type that gives the highest profit. Hence, it has a continuation value $\widetilde{V}_V(U,E)$ which equals

$$\widetilde{V}_V(U,E) = \max\left\{\widetilde{V}_V(U), \widetilde{V}_V(E)\right\}.$$

Ex ante, a firm do not know whether it will get (i) no applications, (ii) only unemployed applicants, (iii) only employed applicants, or (iv) both unemployed and employed applicants. The continuation value before the applications are sent therefore equals

$$\begin{aligned}\widetilde{V}_V &= e^{-\phi_U}e^{-\phi_E}V_V + \left(1-e^{-\phi_U}\right)e^{-\phi_E}\widetilde{V}_V(U) + e^{-\phi_U}\left(1-e^{-\phi_E}\right)\widetilde{V}_V(E) \\ &\quad + \left(1-e^{-\phi_U}\right)\left(1-e^{-\phi_E}\right)\widetilde{V}_V(U,E).\end{aligned}$$

This expression allows me to write the value of a vacancy as follows.

$$V_V = -k + \frac{1}{1+r}\widetilde{V}_V.$$

I assume free entry of firms. Hence, firms will decide to enter the market as long as V_V is positive.

After describing the payoff and strategies of both workers and firms, I now define an equilibrium as follows.

Definition 1 *A market equilibrium is a tuple* $\left\{v, \{F_x\}_{x\in[h,y]}, \lambda, \{w_R(x)\}_{x\in[h,y]}\right\}$ *such that*

1. *Profit maximization:* $\widetilde{V}_V(w|x) = \widetilde{V}_V(x) \equiv \max_{w'} \widetilde{V}_V(w'|x)$ *for all* $w \in \mathscr{F}_x$*, and for all* $x \in \mathscr{G}'$.
2. *Optimal entry decision:* $\begin{cases} V_V = 0 & \text{if } v > 0 \\ V_V \leq 0 & \text{if } v = 0 \end{cases}$
3. *Optimal candidate selection:* $\begin{cases} \widetilde{V}_V(U) \leq \widetilde{V}_V(E) & \text{if } \lambda = 0 \\ \widetilde{V}_V(U) = \widetilde{V}_V(E) & \text{if } \lambda \in (0,1) \\ \widetilde{V}_V(U) \geq \widetilde{V}_V(E) & \text{if } \lambda = 1 \end{cases}$
4. *Optimal reservation wage:* $\begin{cases} \widetilde{V}_E(w) \geq \widetilde{V}_U & \text{for all } w \geq w_R(h) \\ \widetilde{V}_E(w) \leq \widetilde{V}_U & \text{for all } w < w_R(h) \\ \widetilde{V}_E(w) \geq \widetilde{V}_E(x) & \text{for all } w \geq w_R(x), \text{ and for all } x \in \mathscr{G} \\ \widetilde{V}_E(w) \leq \widetilde{V}_E(x) & \text{for all } w < w_R(x), \text{ and for all } x \in \mathscr{G} \end{cases}$

3 Market Equilibrium

3.1 Firms' Candidate Selection and Wage Setting

First, firms decide whether they will enter the market. The free entry condition implies that entry will take place as long as the value V_V of having a vacancy is positive. Hence, in any equilibrium with a positive measure of firms V_V equals 0. Consider a firm giving employment to a worker at wage w. The Bellman equation for its value function is given by (5). Solving this equation for $V_F(w)$ and substituting $V_V = 0$ yields

$$V_F(w) = \frac{(1+r)(y-w)}{r+\delta+(1-\delta)\xi(w)}. \tag{7}$$

On the other hand, a firm with a vacancy that offers a wage w to an applicant currently earning x, has a continuation value given that is given by equation (6). The firm's aim is to maximize this value with respect to w. In section 3.2 I show that all workers follow a reservation wage strategy. Workers never accept wage offers below their reservation wage $w_R(x)$, but are willing to accept higher offers. This implies that the matching probability $m_F(w|x)$ and consequently the firm's payoff equal zero for $w < w_R(x)$.

In the interval $(w_R(x), y]$, a firm faces a trade-off. A higher wage offer lowers the future per-period profit, but is more likely to be accepted by the candidate. To be precise, the worker will accept the wage offer if it is higher than all j other wage offers. If a firm offers the job to a worker, the conditional probability that she has sent n applications equals $\frac{np_s(n)}{\sum_{n=1}^{\infty} np_s(n)} = \frac{np_s(n)}{\alpha_s}$,where $p_s(n) = e^{-\alpha_s}\frac{\alpha_s^n}{n!}$. The probability that the $n-1$ other applications result in exactly j job offers is given by $\begin{pmatrix} n-1 \\ j \end{pmatrix} \psi_s^j (1-\psi_s)^{n-1-j}$. For $w > w_R(x)$, $m_F(w|x)$ therefore equals

$$\begin{aligned} m_F(w|x) &= \sum_{n=1}^{\infty} \frac{ne^{-\alpha_s}\frac{\alpha_s^n}{n!}}{\alpha_s} \sum_{j=0}^{n-1} \begin{pmatrix} n-1 \\ j \end{pmatrix} \psi_s^j (1-\psi_s)^{n-1-j} F_x^j(w) \\ &= \sum_{n=1}^{\infty} e^{-\alpha_s} \frac{\alpha_s^{n-1}}{(n-1)!} (1-\psi+\psi F_x(w))^{n-1} \\ &= e^{-\alpha_s \psi_s (1-F_x(w))}. \end{aligned} \tag{8}$$

Hence, the number of other, better offers follows a Poisson distribution with mean equal to $\alpha_s \psi_s (1-F_x(w))$. Next, I show that the number of $F_x(w)$ is continuous with connected support.

Lemma 1 *Given $v > 0$ and $w_R(h) < y$, in any market equilibrium, $F_x(w)$ is continuous with connected support.*

Proof. The proof is identical to the one given in lemma 1 of Gautier and Moraga-González (2005), which extends lemma 1 of Burdett and Judd (1983). The intuition is as follows. The matching technology implies that some workers compare wages because they get at least two job offers, while others do not have this possibility since they only receive one job offer. This feature implies that if all firms offer the same wage $w < y$, a deviant can do better by offering a marginally higher wage, which allows it to attract workers that compare multiple job offers. At the same time, posting $w = y$, giving a match payoff of zero, is dominated by posting $w_R(x)$ since there is a strictly positive probability that the candidate does not compare wages. Hence, firms post wages according to a mixed strategy. ■

This lemma allows me to derive the following result.

Proposition 1 *Given $v > 0$ and $w_R(h) < y$, in any market equilibrium, firms post prices according to*

$$F_x(w) = \begin{cases} 0 & \text{if } w \leq w_R(x) \\ \frac{1}{\alpha_s \psi_s} \log\left(\frac{y-w_R(x)}{y-w}\right) & \text{if } w \in \mathscr{F}_x = (w_R(x), \overline{w}(x)], \text{ for all } x \in [h, y] \\ 1 & \text{if } w > \overline{w}(x), \end{cases} \tag{9}$$

where $\overline{w}(x)$ equals

$$\overline{w}(x) = y - \exp(-\alpha_s \psi_s)(y - w_R(x)). \tag{10}$$

Proof. First, note that the infimum of the support of $F_x(w)$ must equal $w_R(x)$. Offers below $w_R(x)$ are rejected and give a payoff of zero. On the other hand, if the infimum of the support would be strictly larger than $w_R(x)$, the firm posting the lowest wage in the market could decrease its offer and make a higher profit. Second, let $\overline{w}(x)$ denote the upper bound of the support of $F_x(w)$, hence $\mathscr{F}_x = (w_R(x), \overline{w}(x)]$.[8] The equilibrium definition now implies that the payoff for the firm must be the same for each $w \in \mathscr{F}_x$. Hence, an expression for the wage offer distribution $F_x(w)$ for $w \in \mathscr{F}_x$ follows from the condition

$$\widetilde{V}_V(w_R(x)|x) = \widetilde{V}_V(w|x).$$

Substituting equations (6), (7), and (8), and simplifying the result gives

$$\frac{e^{-\alpha_s \psi_s}(y - w_R(x))}{r + \delta + (1-\delta)\xi(w_R(x))} = \frac{e^{-\alpha_s \psi_s (1 - F_x(w))}(y - w)}{r + \delta + (1-\delta)\xi(w)}.$$

Solving for $F_x(w)$ yields

$$F_x(w) = \frac{1}{\alpha_s \psi_s} \log\left(\frac{r + \delta + (1-\delta)\xi(w)}{r + \delta + (1-\delta)\xi(w_R(x))} \cdot \frac{y - w_R(x)}{y - w}\right).$$

Firms always offer wages that are acceptable to the worker, i.e. above $w_R(x)$. This implies that $\xi(x) = 1 - e^{-\alpha_E \psi_E}$ and therefore the expression for the equilibrium wage offer distribution reduces to

$$F_x(w) = \frac{1}{\alpha_s \psi_s} \log\left(\frac{y - w_R(x)}{y - w}\right).$$

The upper bound $\overline{w}(x)$ of the support of $F_x(w)$ follows from solving $F_x(\overline{w}(x)) = 1$, which gives

$$\overline{w}(x) = y - e^{-\alpha_s \psi_s}(y - w_R(x)).$$

■

Next, I turn to the selection probability λ. A firm that receives applications from both unemployed and employed workers can choose which type it wants to select. This choice is not trivial. Unemployed workers are cheaper because they have worse outside options. But as a result, competition for these workers is higher, which reduces the probability that the job offer will result in a match. Let $\widetilde{V}_V(U)$ denote the firm's continuation value after offering the job to an unemployed worker. The equal profit condition implies

$$\widetilde{V}_V(U) = \frac{(1+r)e^{-\alpha_U \psi_U}(y - w_R(h))}{r + \delta + (1-\delta)(1 - e^{-\alpha_E \psi_E})}.$$

Firms that select an employed worker do initially not know her current wage. Therefore, the continua-

[8] Since we assume that workers reject wage offers that are equal to their reservation wage, $w_R(x)$ is not in the support. Changing this assumption does not affect any conclusions, but complicates notation since then both unemployed and employed workers could have a per-period income of h.

tion value $\widetilde{V}_V(E)$ follows from taking the expectation of $\widetilde{V}_V(x)$.

$$\begin{aligned}\widetilde{V}_V(E) &= \int \widetilde{V}_V(x)\,dG(x)\,. \\ &= \frac{(1+r)\,e^{-\alpha_E\psi_E}\left(y-\int w_R(x)\,dG(x)\right)}{r+\delta+(1-\delta)\left(1-e^{-\alpha_E\psi_E}\right)}.\end{aligned}$$

Firms having both types of applicants compare $\widetilde{V}_V(U)$ and $\widetilde{V}_V(E)$ to decide which candidate to select. Both $\widetilde{V}_V(U)$ and $\widetilde{V}_V(E)$ depend on λ through the job offer probabilities ψ_U and ψ_E.

Proposition 2 *Given $v>0$, an equilibrium value for λ exists.*

Proof. The existence of an equilibrium value for λ is guaranteed by Kakutani fixed point theorem. Consider a firm that has to decide on λ. If all other firms choose $\lambda' \in [0,1]$, the firm either (i) strictly prefers unemployed workers ($\widetilde{V}_V(U) > \widetilde{V}_V(E) \Rightarrow \lambda = 1$), (ii) strictly prefers employed workers ($\widetilde{V}_V(U) < \widetilde{V}_V(E) \Rightarrow \lambda = 0$), or (iii) is indifferent between both types ($\widetilde{V}_V(U) = \widetilde{V}_V(E) \Rightarrow \lambda \in [0,1]$). This best-response function has a fixed point, which determines the equilibrium value of λ. ■

3.2 Workers' Reservation Wage

The strategy of workers consists of the decision whether or not to accept the best wage offer w given their current wage or home production x and the firms' strategies. Conjecture that the workers' value function of employment $V_E(x)$ is strictly increasing in x. This implies that workers follow a reservation wage strategy. The reservation wage $w_R(x)$ is defined by the reservation wage property

$$\begin{cases} V_U = V_E(w_R(h)) \\ V_E(x) = V_E(w_R(x)) \quad \text{for all } x \in \mathscr{G}. \end{cases} \tag{11}$$

Hence, $w_R(x) = x$ for all $x \in \mathscr{G}$, meaning that employed workers accept all wage offers higher than their current wage. This is not necessarily the case for unemployed workers. They take into account that if they accept a job, their job offer arrival rate will decrease. In order to derive the reservation wage $w_R(h)$ of unemployed workers, I first derive explicit expressions for the workers' value functions

Lemma 2 *Given a reservation wage* $w_R(x)$ for all $x \in \mathscr{G}'$ and $v > 0$, *in any market equilibrium, the workers' value functions are given by*

$$V_U = h + \frac{\left(\frac{\delta}{r} + \Upsilon_U\right) w_R(h) + \left(\frac{1-\delta}{r}(1-\Upsilon_E) + 1 - \Upsilon_U\right) y}{1+r-(1-\delta)\Upsilon_E} \tag{12}$$

$$V_E(x) = (1+r)\frac{x + \frac{\delta}{r} w_R(h) + \frac{1-\delta}{r}(1-\Upsilon_E)\,y}{1+r-(1-\delta)\Upsilon_E} \tag{13}$$

where

$$\Upsilon_s = e^{-\alpha_s \psi_s}\left(1+\alpha_s \psi_s\right).$$

Proof. See appendix A.1. ■

Note that $V_E(x)$ is indeed strictly increasing in x, which confirms that a reservation wage strategy is optimal for the workers. Evaluating equation (13) in $w_R(h)$ and equating it to equation (12) gives the solution for the workers' reservation wage. The results on the worker's reservation wages are summarized in the following proposition.

Proposition 3 *Given $v > 0$, in any market equilibrium, the workers' reservation wage $w_R(x)$* is given by

$$w_R(x) = \begin{cases} \frac{(1+r-(1-\delta)\Upsilon_E)h+(\delta(1-\Upsilon_E)+\Upsilon_E-\Upsilon_U)y}{1+r+\delta-\Upsilon_U} & \text{for } x = h \\ x & \text{for all } x \in \mathcal{G}. \end{cases} \tag{14}$$

Proof. See appendix A.2. ■

It is straightforward to check that $w_R(h) > h$ since $\alpha_U \psi_U > \alpha_E \psi_E$. In other words, workers are choosy because they realize that their job offer arrival rate will fall after accepting a job. This result is in line with Burdett and Mortensen (1998).

3.3 Equilibrium Characterization

By combining the equilibrium elements derived above, we can now prove the following result.

Proposition 4 *A market equilibrium with a positive measure of firms, i.e. $v > 0$, exists for $k < \frac{1}{r+\delta}(y-h)$.* For $k \geq \frac{1}{r+\delta}(y-h)$, the market collapses.

Proof. Proposition 1, 2, and 3 describe the market equilibrium in case a positive measure of firms enters the market. Hence, in order to complete the derivation the entry decision of firms has to be considered. First, consider a situation in which the number of firms tends to zero, i.e. $v \to 0^+$. This implies that $\phi_s \to \infty$, $\psi_s \to 0$, and $\Upsilon_s \to 1$. As a result, the reservation wage of an unemployed worker goes to h, i.e. $w_R(h) \to h$. In fact, the wage offer distribution becomes degenerate at h, since $\overline{w}(h) \to h$. This implies that $\widetilde{V}_V \to \frac{1+r}{r+\delta}(y-h)$, and thus that $V_V \to -k + \frac{1}{r+\delta}(y-h) > 0$. Hence, as long as $k < \frac{1}{r+\delta}(y-h)$ some firms will enter the market. If $k \geq \frac{1}{r+\delta}(y-h)$ firms do not want to enter and the market collapses. Next, consider a situation in which the number of firms is much larger than the number of workers, i.e. $\phi_s \to 0$. Then $V_V \to -\frac{1+r}{r}k < 0$. Since V_V is continuous in v, there exists a value for v such that $V_V = 0$. Hence, a market equilibrium exists.[9] ■

[9] Note that although proving the existence of an equilibrium is straightforward, establishing whether it is unique or not is very complicated. The main reason for this is the fact that $\widetilde{V}_V(E)$ depends on the earnings distribution $G(w)$, for which no closed-form expression exists. See section 4 for more details.

In the market equilibrium, wages range from the reservation wage $w_R(h)$ up to the net productivity y. This contrasts the models by Burdett and Judd (1983) and Burdett and Mortensen (1998), where the upper bound of the wage density is strictly smaller than the productivity level. A second difference compared to both models, is that not all wage levels can be reached directly from unemployment. In the first job after unemployment, a worker can never earn more than $\overline{w}(h)$, which is strictly lower than $y-k$. A worker who earns that upper bound and receives a job offer in the next period, can never earn more than $\overline{w}(\overline{w}(h))$ in that new job. By mathematical induction, one can show that the maximum wage $\hat{w}_{U,n}$ a worker can earn in her n^{th} job after unemployment is equal to

$$\hat{w}_{U,n} = \overline{w}^n(h) = y - e^{-\alpha_U \psi_U - \alpha_E \psi_E (n-1)} (y - w_R(h)) \text{ for } n \in \mathbb{N} \setminus \{0\}.$$

Hence, the wage distribution can be seen as a wage ladder. Workers have to climb one rung (i.e. find a job in $(\hat{w}_{U,n-1}, \hat{w}_{U,n}]$) before they can climb the next. In this respect, the model is similar to Delacroix and Shi (2006), who describe such a ladder in a directed search framework. However, an important difference exists between their model and my model. They find a wage distribution with a finite number of mass points as support. Workers choose to only apply to firms that offer a wage that is one rung higher than their current wage level. Hence, the speed with which workers climb the ladder is fixed. My model allows for variation in this speed. Some workers can experience larger wage increases between two jobs than others, which is in line with what one typically observes in reality.

The equilibrium unemployment level u can be calculated by equating inflow and outflow. In each period a fraction δ of the employed workers loses its job. Hence, inflow equals $\delta(1-u)$. Workers leave unemployment if they get at least one job offer, implying that outflow is equal to $u(1-e^{-\alpha_U \psi_U})$. Solving for u yields

$$u = \frac{\delta}{1 - e^{-\alpha_U \psi_U} + \delta}. \tag{15}$$

4 Earnings Distribution

4.1 Analytical Expression

In this section I describe the earnings density $g(w)$, i.e. the steady state cross-sectional wage density in the market equilibrium. In order to derive the earnings density, I consider the set $\mathscr{X}(w)$ of employed workers earning a wage lower than w. By definition the probability that a worker is included in this set is given by $G(w)$. I exploit the fact that in steady state inflow into and outflow from $\mathscr{X}(w)$ should be equal. Note that workers never move to jobs paying a lower wage, implying that inflow only occurs from unemployment. Further, note that unemployed workers flow into $\mathscr{X}(w)$ if the best wage offer they get is lower than w. Hence, inflow into the set of workers earning less than w, denoted by $I(w)$, equals

$$I(w) = u \sum_{j=1}^{\infty} \chi_U(j) F_h^j(w). \tag{16}$$

On the other hand, outflow from $\mathscr{X}(w)$ can occur for two reasons. All employed workers are subject to a job destruction shock at rate δ, in which case they flow back to unemployment. The ones that are not hit by the shock have the opportunity to leave the group by getting a job offer paying more than w. So, outflow $O(w)$ equals

$$O(w) = (1-u) \int_{w_R(h)}^{w} \left(\delta + (1-\delta) \sum_{j=1}^{\infty} \chi_E(j) \left(1 - F_x^j(w)\right) \right) g(x)\,dx. \tag{17}$$

Equating inflow and outflow and rewriting the result gives the following integral equation:

$$\frac{u}{1-u} \sum_{j=1}^{\infty} \chi_U(j) F_h^j(w) = \delta G(w) + (1-\delta) \int_{w_R(h)}^{w} \sum_{j=1}^{\infty} \chi_E(j) \left(1 - F_x^j(w)\right) g(x)\,dx. \tag{18}$$

Solving this equation gives the expression for the earnings distribution $G(w)$ and taking the first derivative of this expression yields the density $g(w)$. Note that the support of each $F_x(w)$ does not correspond to $\mathscr{G}$. Therefore, the functional form of $G(w)$ varies across subintervals on its support.

In order to derive these subintervals, I define two sets of cutoff points. The first set consists of the maximum wages $\hat{w}_{U,n}$, $n \in \mathbb{N} \backslash \{0\}$ a worker can earn in her n^{th} job after unemployment , as derived in section 3.3. The second set follows from considering a worker that is employed at the lowest wage in the economy, i.e. $w = w_R^+ \equiv \lim_{\varepsilon \downarrow 0} w_R(h) + \varepsilon$. She can never earn more than $\overline{w}\left(w_R^+\right)$ in her next job and never more than $\overline{w}\left(\overline{w}\left(w_R^+\right)\right)$ in the job after that. Let $\hat{w}_{E,n}$ denote the maximum wage this worker can earn in her n^{th} job. Hence,

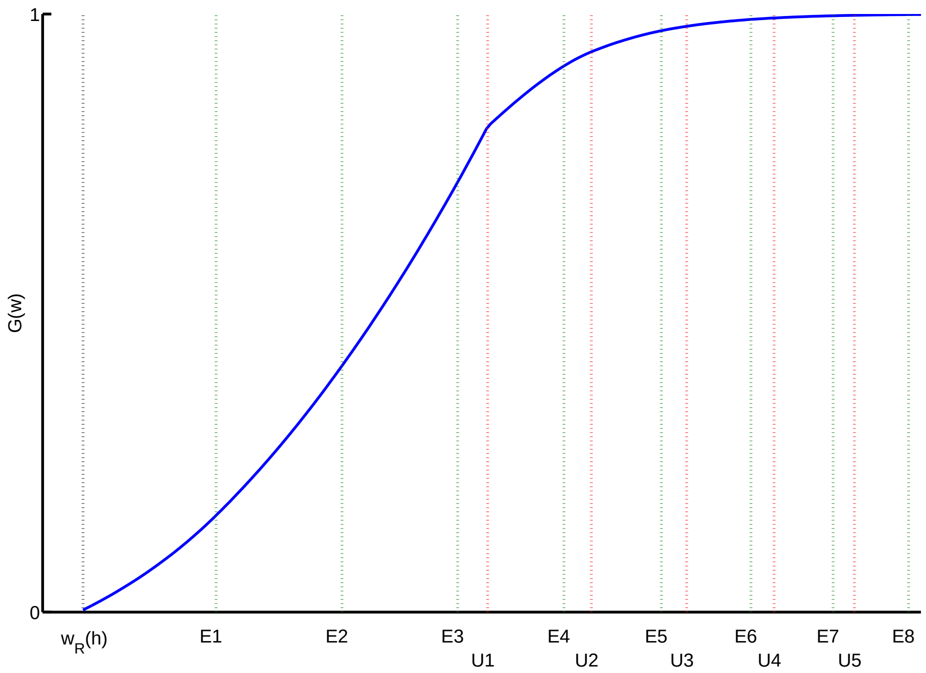
$$\hat{w}_{E,n} \equiv \overline{w}^n\left(w_R^+\right) = y - e^{-\alpha_E \psi_E n}\left(y - w_R^+\right) \text{ for } n \in \mathbb{N} \backslash \{0\}.$$

Next, combine both sets of cutoff points and let $\hat{w}_n$ be the n^{th} order statistic of the new set, i.e. the n^{th} smallest value. Note that $\hat{w}_{U,1} > \hat{w}_{E,1}$, implying that $\hat{w}_1 = \hat{w}_{E,1}$. Let $\hat{w}_{E,\hat{n}}$ be the largest $\hat{w}_{E,n}$ smaller than $\hat{w}_{U,1}$. Then it is straightforward to show that the cutoff points $\hat{w}_{U,n}$ and $\hat{w}_{E,n}$ alternate from $\hat{w}_{U,1}$ onwards. Hence

$$\begin{aligned} &\{\hat{w}_0, \hat{w}_1, \hat{w}_2, \ldots, \hat{w}_{\hat{n}}, \hat{w}_{\hat{n}+1}, \hat{w}_{\hat{n}+2}, \hat{w}_{\hat{n}+3}, \ldots\} \\ &= \{w_R(h), \hat{w}_{E,1}, \hat{w}_{E,2}, \ldots, \hat{w}_{E,\hat{n}}, \hat{w}_{U,1}, \hat{w}_{E,\hat{n}+1}, \hat{w}_{U,2}, \ldots\}. \end{aligned}$$

Figure 1 illustrates this by showing the cutoff points for arbitrary parameter choices.

In appendix A.3, I show that the functional form of $G(w)$ and $g(w)$ is different on each interval $(\hat{w}_{n-1}, \hat{w}_n]$. Since $\lim_{n \to \infty} \hat{w}_n = y - k$, there exist infinitely many of such intervals. Hence, I partition



Note that $\hat{w}_{E,n} < \hat{w}_{U,1}$ for $n \leq \hat{n}$ (here $\hat{n} = 3$). After $\hat{w}_{E,\hat{n}}$, the cutoff points formed by $\hat{w}_{U,i}$ and $\hat{w}_{E,\hat{n}+i}$ alternate.

Figure 1: Illustration of cutoff points.

the earnings distribution and density as follows

$$\{G(w), g(w)\} = \begin{cases} \{G_1(w), g_1(w)\} & w \in (w_R(h), \hat{w}_1] \\ \{G_n(w), g_n(w)\} & w \in (\hat{w}_{n-1}, \hat{w}_n], n \in \mathbb{N} \setminus \{0,1\}. \end{cases}$$

First, I obtain a closed-form expression for $G_1(w)$. Then, I show that the elements of the wage distribution satisfy a recursive structure: knowledge of $G_{n-1}(w)$ or $G_{n-2}(w)$ is sufficient to derive $G_n(w)$. Taking derivatives yields expressions for $g_1(w)$, $g_2(w)$, $g_3(w)$, et cetera. Hence, the entire earnings density can be characterized by the initial element $G_1(w)$ and a recursive equation. This is summarized in proposition 5.

Proposition 5 *In market equilibrium, the earnings distribution is characterized by the following recursive system*

$$\begin{cases} G_1(w) &= \delta\Psi_U\left(\left(\frac{\pi_{w_R(h)}}{\pi_w}\right)^{\Delta_E} - 1\right) \\ G_n(w) &= C_n - \delta\Psi_U + (1-\delta)\left(G_{n-1}(\underline{w}(w)) - \pi_w^{-\Delta_E}\int \pi_w^{\Delta_E} dG_{n-1}(\underline{w}(w))\right) \\ & \quad \textit{if } n \in \{2,\ldots,\hat{n}+1\} \\ G_n(w) &= C_n + \delta + (1-\delta)\left(G_{n-2}(\underline{w}(w)) - \pi_w^{-\Delta_E}\int \pi_w^{\Delta_E} dG_{n-2}(\underline{w}(w))\right) \\ & \quad \textit{if } n \in \{\hat{n}+2,\ldots\}, \end{cases}$$

where $\Delta_E = \frac{1}{1-(1-\delta)e^{-\alpha_E \psi_E}}$, $\Psi_U = \frac{e^{-\alpha_U \psi_U}}{1-e^{-\alpha_U \psi_U}}$, $\underline{w}(w) = y - e^{\alpha_E \psi_E}(y-w)$, *and* C_n *is determined by* $G_n(\hat{w}_{n-1}) = G_{n-1}(\hat{w}_{n-1})$.

Proof. See appendix A.3. ■

The complexity of $G_n(w)$ increases rapidly in n, which impedes derivation of analytical expressions. However, it is straightforward to see that together they create a non-monotonic wage density. The intuition is as follows. In order to be employed at a low wage, a worker must have gotten a low wage offer after an unemployment spell and have remained there since that moment. On the other hand, in order to earn a really high salary, the worker must have experienced many consecutive job-to-job transitions without a job destruction shock in between. The probability of both events is relatively small and therefore the equilibrium fractions of workers earning these wages are small. Intermediate wage levels are much more common, also because there are several ways in which one can obtain such a salary. Some workers get this wage directly after unemployment, while others experience a couple of job-to-job transitions before finding a job paying this wage.

4.2 Simulation

Since analytical expressions for $g_n(w)$ become very complicated, I use simulation to present some features of the equilibrium. Numerical calculation of $g(w)$ is straightforward, since the model has the Markov property: the wage of a worker in the next period solely depends on her current wage and not directly on her past wages. Hence, a numerical approximation of $g(w)$ can be obtained by choosing a sufficiently dense grid of wages[10] and by calculating the normalized left eigenvector of the transition matrix associated with eigenvalue 1. In order to do this, I normalize the output y to 1 and set household production h equal to 0.4. Furthermore I fix the number of vacancies per unemployed (i.e. the labor market tightness) to 1. I assume that the length of a period equals 1 month and set the interest rate equal to 5% per year, which corresponds to $r = 0.004$. In line with the data used by Shimer (2007), I set the job destruction rate δ equal to 0.0173. Further, I assume that $\alpha_U = \alpha_E = 2$.

The equilibrium values of the parameters are given in table 1. Firms are indifferent between unemployed and employed workers and offer the job with probability 0.304 to an unemployed if they have both types of applicants. The reservation wage of an unemployed worker is equal to 0.728. About 7% of the population is unemployed, while the entry costs for firms equal 2.786. The job offer arrival rate for unemployed is almost 5 times as higher as for employed, reflecting the fact that unemployed would be more attractive in case competition for both types is the same. Figure 2 shows the earnings distribution for three different values of the job destruction rate, i.e. $\delta \in \{0.0133, 0.0173, 0.0213\}$. The discontinuity in each of the graphs reflects the ladder structure of the distribution: it occurs at the maximum wage that workers can get in their first job after unemployment.

The model presented here is also a useful tool for policy analysis. There is a large literature on the

[10] I use a grid with 500 points of support between the reservation wage w_R and the productivity y.

Parameter	Value
λ	0.304
$w_R(h)$	0.728
k	2.786
u	0.070
$\alpha_U \psi_U$	0.263
$\alpha_E \psi_E$	0.056

Table 1: Equilibrium parameter values

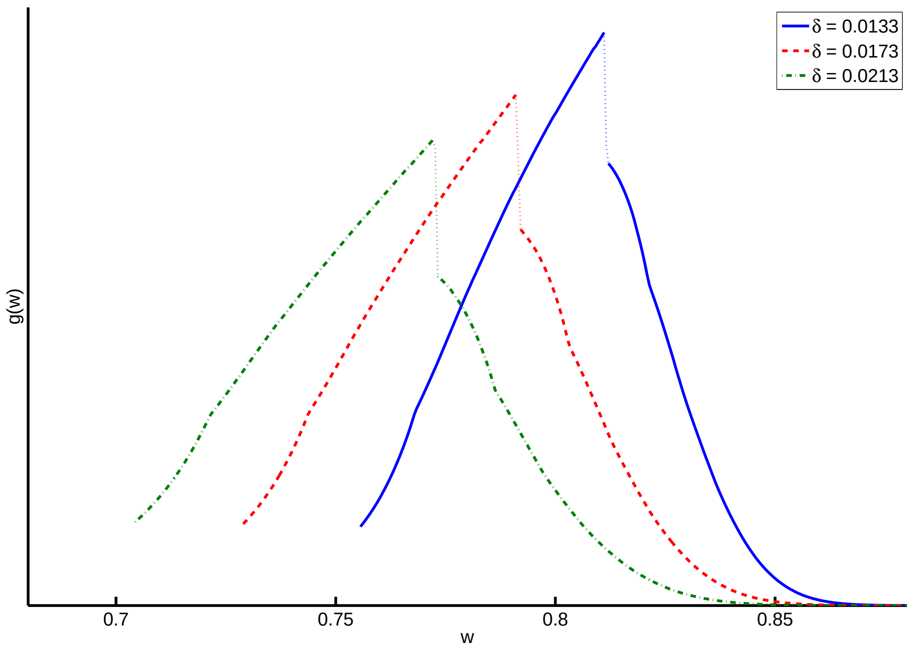


Figure 2: Earnings distribution

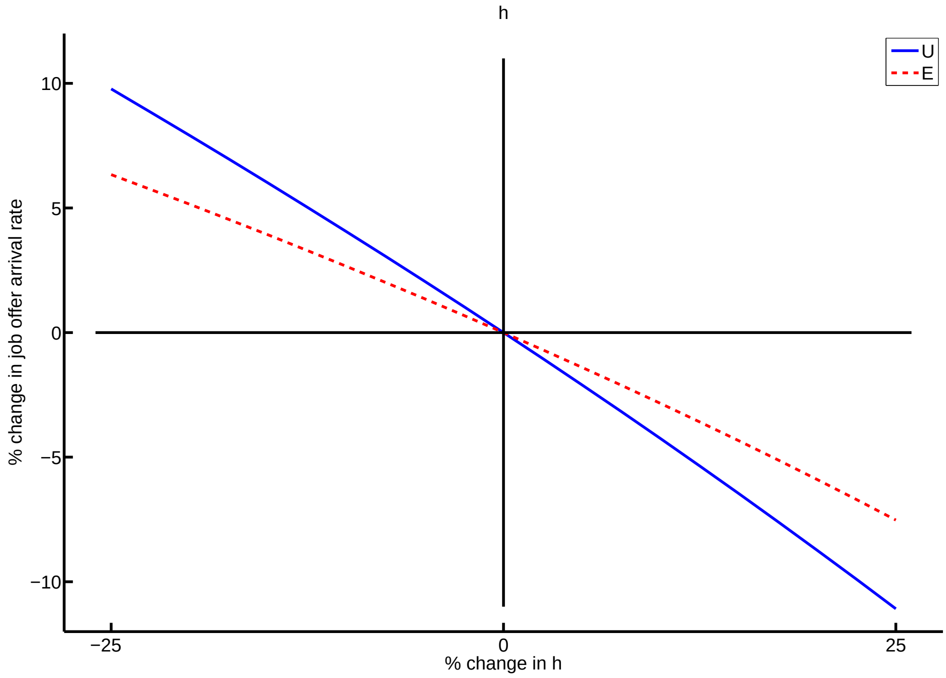


Figure 3: Effect of a change in the home production h on the job offer arrival rates

effect of active labor market programs or policy reforms on the job finding rate of unemployed (see Heckman et al., 1999). However, many of those studies do not take equilibrium effects into account. In reality, such equilibrium effects are clearly important. Any policy that affects outcomes for unemployed changes the size and/or composition of the pool of employed workers and is therefore likely to have an effect on job-to-job transitions as well. The microfoundation for the matching technology in my model makes it possible to study how a change in the exogenous parameters influences the job offer arrival rates of both unemployed and employed. To illustrate this, I simulate changes in the home production h and the job destruction rate δ. Figures 3 and 4 show the results.

Not surprisingly, there exists a negative relationship between h and the job offer arrival rates. An increase in h raises the reservation wage $w_R(h)$ of the unemployed, which makes it more expensive to hire these workers. As a result the wages of employed become higher as well. Both effects reduce the profits of firms, implying some firms will leave the market and the job offer arrival rates will drop. I find that the result is stronger for workers without a job than for employed workers, which can be explained by the fact that firms will update their value of λ. The higher reservation wage of the unemployed is a direct effect of the increase in h, while the higher wages of the employed are an indirect and smaller effect. Hence, firms will choose more often for an on-the-job searcher now. This substitution aggravates the effect on the unemployed workers.

For the job destruction rate I find opposite effects. The job offer arrival rates are increasing in δ and the elasticity is larger for employed workers. When jobs are destroyed more frequently, the reservation

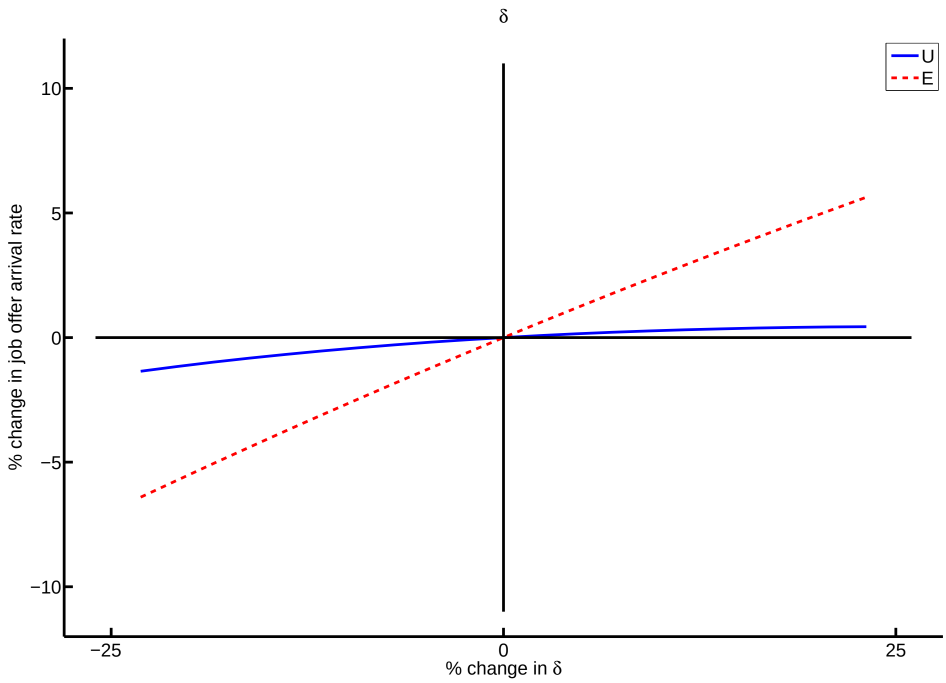


Figure 4: Effect of a change in the job destruction rate δ on the job offer arrival rates

wage of the unemployed goes down. As a result the wages earned by employed workers decrease as well, which stimulates entry. Hence, both types of workers are more likely to receive a job offer. However, the increase in δ also increases unemployment, implying that individuals without a job now have more competitors than before, if a firm decides to offer the job to an unemployed worker. This reduces the effect on the job offer arrival rate of unemployed.

5 Conclusions

I have presented an equilibrium search model of the labor market in which workers can send multiple applications simultaneously and can search for a better job while employed. Unlike most of the literature, I allow firms to condition their wage offers on the current wage of their job candidates. Wage dispersion is maintained because firms take into account that they might have to compete with other firms for the same worker. I obtain an earnings density that has continuous support, a unique interior mode, and a long right tail, even in a market with identical firms and workers. This feature of the model is relevant for empirical work. The model can easily be extended to include heterogeneity on the firm and/or worker side and can therefore be used to answer an important empirical question: what are the relative contributions of search and coordination frictions, on-the-job search, and productivity differences to wage dispersion?

The model can also be used to improve the evaluation of active labor market programs. I argue that policies affecting the job finding rates of unemployed can be expected to have an effect on job-to-job transitions as well. The framework presented here takes such equilibrium effects into account. For example, the model predicts that lower unemployment benefits do not only increase the job finding rates of the unemployed but also of the employed. Ignoring such effects could potentially lead to wrong conclusions about the desirability of certain policy reforms.

A Proofs

A.1 Proof of Lemma 2

The Bellman equations for V_U and $V_E(x)$ are given by equations (2) and (3). Both satisfy Blackwell's (1965) sufficient conditions for a contraction mapping, implying that a unique solution for V_U and $V_E(x)$ exists. Conjecture that the solution for $V_E(x)$ is a linear function of x, i.e. $V_E(x) = \beta_0 + \beta_1 (x - w_R(h))$ for some unknown constants β_0 and β_1. Substitute this into the Bellman equation given by (3) and (4), and use reservation wage property (11) to get

$$\begin{aligned} V_E(x) &= x + \frac{\beta_0}{1+r} + \frac{(1-\delta)\beta_1}{1+r} \times \\ & \left(\sum_{j=1}^{\infty} \chi_E(j|\alpha_E) \int_{w \in \mathscr{F}_x} w dF_x^j(w) + \chi_E(0|\alpha_E)x - w_R(h) \right) \end{aligned} \tag{19}$$

By substituting equations (1) and (9), I obtain

$$\begin{aligned} \sum_{j=1}^{\infty} \chi_E(j|\alpha_E) \int_x^{\overline{w}(x)} w dF_x^j(w) &= \int_x^{\overline{w}(x)} w d \sum_{j=1}^{\infty} e^{-\alpha_E \psi_E} \frac{(\alpha_E \psi_E F_x(w))^j}{j!} \\ &= \int_x^{\overline{w}(x)} w d \left(e^{-\alpha_E \psi_E (1-F_x(w))} - e^{-\alpha_E \psi_E} \right) \\ &= e^{-\alpha_E \psi_E} \int_x^{\overline{w}(x)} w d \frac{\pi_x}{\pi_w}. \end{aligned}$$

Partial integration gives

$$\begin{aligned} \int_x^{\overline{w}(x)} w d \frac{\pi_x}{\pi_w} &= \left[w \frac{\pi_x}{\pi_w} \right]_x^{\overline{w}(x)} - \int_x^{\overline{w}(x)} \frac{\pi_x}{\pi_w} dw \\ &= \overline{w}(x) \frac{\pi_x}{\pi_{\overline{w}(x)}} - x + \pi_x \left[\log(\pi_w) \right]_x^{\overline{w}(x)} \\ &= (e^{\alpha_E \psi_E} - 1) y - \alpha_E \psi_E (y - x) \end{aligned}$$

Hence

$$\sum_{j=1}^{\infty} \chi_E(j|\alpha_E) \int_x^{\overline{w}(x)} w dF_x^j(w) = \left(1 - e^{-\alpha_E \psi_E}\right) y - \alpha_E \psi_E e^{-\alpha_E \psi_E} (y - x).$$

This result can be used to rewrite (19) as follows

$$\begin{aligned}
V_E(x) &= x+\frac{\beta_0}{1+r}+\frac{(1-\delta)\beta_1}{1+r}(y-w_R(h)-\Upsilon_E(y-x)). \qquad (20)\\
&= \left[w_R(h)+\frac{\beta_0}{1+r}+\frac{(1-\delta)\beta_1}{1+r}(1-\Upsilon_E)(y-w_R(h))\right]\\
&\quad+\left[1+\frac{(1-\delta)\beta_1}{1+r}\Upsilon_E\right](x-w_R(h)),
\end{aligned}$$

where

$$\Upsilon_s = e^{-\alpha_s\psi_s}(1+\alpha_s\psi_s).$$

This confirms the linear structure of $V_E(x)$. The coefficients β_0 and β_1 can be found by solving the system

$$\begin{aligned}
\beta_0 &= w_R(h)+\frac{\beta_0}{1+r}+\frac{(1-\delta)\beta_1}{1+r}(1-\Upsilon_E)(y-w_R(h))\\
\beta_1 &= 1+\frac{(1-\delta)\beta_1}{1+r}\Upsilon_E.
\end{aligned}$$

This yields

$$\beta_0=\frac{1+r}{r}\cdot\frac{(r+\delta)w_R(h)+(1-\delta)(1-\Upsilon_E)y}{1+r-(1-\delta)\Upsilon_E} \qquad (21)$$

and

$$\beta_1=\frac{1+r}{1+r-(1-\delta)\Upsilon_E}. \qquad (22)$$

In the same way in which I derived equation (20), one can obtain the following expression for V_U

$$V_U=h+\frac{\beta_0}{1+r}+\frac{\beta_1}{1+r}(1-\Upsilon_U)(y-w_R(h)).$$

Substituting equations (21) and (22) completes the proof.

A.2 Proof of Proposition 3

Use equations (12), (13), and the reservation wage property $V_U=V_E(w_R(h))$ to obtain

$$h+\frac{\left(\frac{\delta}{r}+\Upsilon_U\right)w_R(h)+\left(\frac{1-\delta}{r}(1-\Upsilon_E)+1-\Upsilon_U\right)y}{1+r-(1-\delta)\Upsilon_E}=(1+r)\frac{\frac{r+\delta}{r}w_R(h)+\frac{1-\delta}{r}(1-\Upsilon_E)y}{1+r-(1-\delta)\Upsilon_E}$$

Solving this expression for $w_R(h)$ yields

$$w_R(h)=\frac{(1+r-(1-\delta)\Upsilon_E)h+(\delta(1-\Upsilon_E)+\Upsilon_E-\Upsilon_U)y}{1+r+\delta-\Upsilon_U}.$$

A.3 Proof of Proposition 5

Recall that I define the following cutoff points:

$$\begin{aligned}&\{\hat{w}_0, \hat{w}_1, \hat{w}_2, \ldots, \hat{w}_{\hat{n}}, \hat{w}_{\hat{n}+1}, \hat{w}_{\hat{n}+2}, \hat{w}_{\hat{n}+3}, \ldots\}\\ &= \{w_R(h), \hat{w}_{E,1}, \hat{w}_{E,2}, \ldots, \hat{w}_{E,\hat{n}}, \hat{w}_{U,1}, \hat{w}_{E,\hat{n}+1}, \hat{w}_{U,2}, \ldots\}.\end{aligned}$$

The functional form of $G(w)$ and $g(w)$ is different on each interval $(\hat{w}_{n-1}, \hat{w}_n]$ and therefore I partition the earnings distribution and density as follows

$$\{G(w), g(w)\} = \begin{cases} \{G_1(w), g_1(w)\} & w \in (h, \hat{w}_1] \\ \{G_n(w), g_n(w)\} & w \in (\hat{w}_{n-1}, \hat{w}_n], n \in \mathbb{N}\setminus\{0,1\}. \end{cases}$$

I derive the earnings distribution in a recursive way. First, I obtain a closed-form expression for $G_1(w)$. After that, I derive a recursive relationship between $G_n(w)$ and $G_{n-1}(w)$ and/or $G_{n-2}(w)$. Throughout the proof I simplify notation by using $\Delta_E = \frac{1}{1-(1-\delta)e^{-\alpha_E \psi_E}}$ and $\Psi_s = \frac{e^{-\alpha_s \psi_s}}{1-e^{-\alpha_s \psi_s}}$.

A.3.1 Derivation of $g_1(w)$

I derive an expression for $g_1(w)$ by considering $\mathscr{X}(w)$, the set of workers earning less than w, for values of w in the interval $(w_R(h), \hat{w}_1]$. First, recall that

$$\sum_{j=1}^{\infty} \chi_s(j|\alpha_s) F_x^j(w) \quad = \quad e^{-\alpha_s \psi_s}\left(e^{\alpha_s \psi_s F_x(w)} - 1\right).$$

Substituting equation (9) gives

$$\sum_{j=1}^{a_s} \chi_s(j|a_s) F_x^j(w) = \begin{cases} 0 & w \leq w_R(x) \\ e^{-\alpha_s \psi_s}\left(\frac{\pi_x}{\pi_w} - 1\right) & w \in (w_R(x), \overline{w}(x)] \\ 1 - e^{-\alpha_s \psi_s} & w > \overline{w}(x). \end{cases} \tag{23}$$

If I substitute this into the steady state equation (18) and multiply both the left and the right hand side with π_w, I get

$$\frac{u}{1-u} e^{-\alpha_U \psi_U}(\pi_h - \pi_w) = \pi_w G_1(w) - (1-\delta) e^{-\alpha_E \psi_E} \int_{w_R(h)}^{w} \pi_x g_1(x)\, dx.$$

I turn this integral equation into a differential equation by taking the first derivative with respect to w. Simplifying the resulting expression by substituting $\frac{u}{1-u} = \frac{\delta}{1-e^{-\alpha_U \psi_U}}$ yields

$$g_1(w) - \frac{\Delta_E}{\pi_w} G_1(w) = \frac{\delta \Psi_U \Delta_E}{\pi_w}.$$

This is a first-order non-homogeneous linear differential equation. Hence, the solution for $G_1(w)$ is given by

$$G_1(w) \quad = \quad \exp\left(\Delta_E \int \frac{1}{\pi_w} dw\right)\left(\int \exp\left(-\Delta_E \int \frac{1}{\pi_w} dw\right) \frac{\delta \Psi_U \Delta_E}{\pi_w} dw + C_1\right),$$

where C_1 is a constant. Solving the integrals and simplifying the resulting expression gives

$$G_1(w) \quad = \quad C_1 \pi_w^{-\Delta_E} - \delta \Psi_U,$$

The value of the constant C_1 follows from the condition $G_1(w_R(h)) = 0$. This implies

$$C_1 = \delta \Psi_U \pi_{w_R(h)}^{\Delta_E}.$$

Hence,

$$G_1(w) = \delta \Psi_U \left(\left(\frac{\pi_{w_R(h)}}{\pi_w}\right)^{\Delta_E} - 1\right). \tag{24}$$

A.3.2 Derivation of $g_2(w), \ldots, g_{\hat{n}+1}(w)$

Next, consider $\mathscr{X}(w)$ for $w \in (\hat{w}_{n-1}, \hat{w}_n]$, $n \in \{2, 3, \ldots \hat{n}+1\}$. In these intervals the inflow still depends on w, as in the derivation of $g_1(w)$. However not all workers can leave $\mathscr{X}(w)$ anymore by a job-to-job transition. The workers earning low wages will stay in $\mathscr{X}(w)$ even if they experience the largest possible wage increase when moving to a new job. Let $\underline{w}(w)$ denote the minimum wage that a worker must earn in order to be able to earn $w > \hat{w}_1$ in his next job. By inverting equation (10), I obtain

$$\underline{w}(w) = y - k - e^{\alpha_E \psi_E}(y - k - w). \tag{25}$$

Note that $\underline{w}(w)$ is strictly increasing in w and that $\underline{w}(\hat{w}_{n-1}) = \hat{w}_{n-2}$, which confirms that workers earning less than $\hat{w}_{n-2}$ cannot leave $\mathscr{X}(w)$ via a job-to-job transition. By using equation (25), I can let the integral in the right hand side of (18) start at $\underline{w}(w)$. Substituting the relevant cases of equation (23) then gives

$$\frac{u}{1-u} e^{-\alpha_U \psi_U} \left(\frac{\pi_{w_R(h)}}{\pi_w} - 1\right) = G(w) - (1-\delta)\left(G(\underline{w}(w)) + e^{-\alpha_E \psi_E} \int_{\underline{w}(w)}^{w} \frac{\pi_x}{\pi_w} g(x)\, dx\right).$$

Note that $G(w) = G_n(w)$, $G(\underline{w}(w)) = G_{n-1}(\underline{w}(w))$, and that $\int_{\underline{w}(w)}^{w} \frac{\pi_x}{\pi_w} g(x)\, dx$ can be rewritten as

$$\int_{\underline{w}(w)}^{w} \frac{\pi_x}{\pi_w} g(x)\, dx = \int_{\underline{w}(w)}^{\hat{w}_{n-1}} \frac{\pi_x}{\pi_w} g_{n-1}(x)\, dx + \int_{\hat{w}_{n-1}}^{w} \frac{\pi_x}{\pi_w} g_n(x)\, dx.$$

Again, I create a differential equation by multiplying both the left hand side and the right hand side with π_w and taking the first derivative with respect to w. This results in the following expression:

$$g_n(w) - \frac{\Delta_E}{\pi_w} G_n(w) = \frac{\Delta_E}{\pi_w} \left(\delta \Psi_U - (1-\delta) G_{n-1}(\underline{w}(w))\right).$$

Like above, this is a first-order non-homogeneous linear differential equation. The solution is equal to

$$G_n(w) = C_n - \delta \Psi_U - (1-\delta) \Delta_E \pi_w^{-\Delta_E} \int \pi_w^{\Delta_E - 1} G_{n-1}(\underline{w}(w)) \, dw.$$

where the constant C_n follows from the condition $G_n(\hat{w}_{n-1}) = G_{n-1}(\hat{w}_{n-1})$. Finally, integration by parts gives

$$G_n(w) = C_n - \delta \Psi_U + (1-\delta) \left(G_{n-1}(\underline{w}(w)) - \pi_w^{-\Delta_E} \int \pi_w^{\Delta_E} dG_{n-1}(\underline{w}(w)) \right).$$

A.3.3 Derivation of $g_{\hat{n}+2}, \ldots$

Next, consider $\mathscr{Z}(w)$ for $w \in (\hat{w}_{n-1}, \hat{w}_n]$, $n \in \{\hat{n}+2, \hat{n}+3, \ldots\}$. In these intervals the inflow no longer depends on w, since unemployed workers finding a job are always hired at a wage below $\hat{w}_n$. Hence, inflow equals

$$I(w) = u\left(1 - e^{-\alpha_U \psi_U}\right).$$

Outflow still depends on w, but again the integral in the right hand side of (18) starts at $\underline{w}(w)$. Hence, the earnings distribution is implied by

$$\frac{u}{1-u}\left(1 - e^{-\alpha_U \psi_U}\right) = G(w) - (1-\delta) G(\underline{w}(w)) - (1-\delta) e^{-\alpha_E \psi_E} \int_{\underline{w}(w)}^{w} \frac{\pi_x}{\pi_w} g(x) \, dx.$$

Note that now both $\hat{w}_{U,n}$ and $\hat{w}_{E,n}$ contribute to the cutoff points, implying that there are twice as many intervals as for $w < \hat{w}_{U,1}$. More specifically, there are two cutoff points between any w and $\underline{w}(w)$. Hence, $G(w) = G_n(w)$, $G(\underline{w}(w)) = G_{n-2}(\underline{w}(w))$, and $\int_{\underline{w}(w)}^{w} \frac{\pi_x}{\pi_w} g(x) \, dx$ can be rewritten as

$$\int_{\underline{w}(w)}^{w} \frac{\pi_x}{\pi_w} g(x) \, dx = \int_{\underline{w}(w)}^{\hat{w}_{n-2}} \frac{\pi_x}{\pi_w} g_{n-2}(x) \, dx + \int_{\hat{w}_{n-2}}^{\hat{w}_{n-1}} \frac{\pi_x}{\pi_w} g_{n-1}(x) \, dx + \int_{\hat{w}_{n-1}}^{w} \frac{\pi_x}{\pi_w} g_n(x) \, dx.$$

Creating a differential equation by multiplying both the left hand side and the right hand side with π_w, and taking the first derivative with respect to w, yields:

$$g_n(w) - \frac{\Delta_E}{\pi_w} G_n(w) = -\frac{\Delta_E}{\pi_w} \left(\delta + (1-\delta) G_{n-2}(\underline{w}(w))\right).$$

Again, this is a first-order non-homogeneous linear differential equation. The solution is equal to

$$G_n(w) = C_n + \delta - (1-\delta)\Delta_E \pi_w^{-\Delta_E} \int \pi_w^{\Delta_E - 1} G_{n-2}(\underline{w}(w))\, dw,$$

where the constant C_n follows from the condition $G_n(\hat{w}_{n-1}) = G_{n-1}(\hat{w}_{n-1})$. Finally, integration by parts gives

$$G_n(w) = C_n + \delta + (1-\delta)\left(G_{n-2}(\underline{w}(w)) - \pi_w^{-\Delta_E} \int \pi_w^{\Delta_E} dG_{n-2}(\underline{w}(w))\right). \tag{26}$$

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