Applications and Interviews

Firms' Recruiting Decisions in a Frictional Labor Market

Online Appendix

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C Calibration Details

C.1 EOPP Data

Background. The Employment Opportunities Pilot Project—developed by the Office of the Assistant Secretary for Policy, Evaluation and Research, and funded by the Department of State's Employment and Training Administration—was introduced in the summer of 1979.[61] It consisted of an intensive job search program combined with a work and training program, organized at 10 pilots sites throughout the country. Each pilot site consisted of a small number of neighboring counties. The program was aimed at unemployed workers with a low family income, and tried to place eligible workers in private-market jobs at one of the pilot sites during a job search assistance program. If these attempts failed, the worker was offered a federally-assisted work or training position. The program was in full operation by the summer of 1980, but was phased out during 1981 by the new Administration.

In order to evaluate the program, a survey was sent to firms at the ten pilot sites and twenty control sites which where selected on the basis of their similarity to the pilot sites. The first wave of the survey took place between March and June 1980. The second wave was conducted between February and July 1982 and aimed to re-interview all respondents to the first survey. The response rate was about 70%.

Representativeness. The data set is not representative of the entire US labor market. Workers in the sample are relatively young and due to the nature of the labor market program, low incomes

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[61]See Barron et al. (1985), Barron et al. (1987), and Burdett and Cunningham (1998) for additional information about the EOPP data.

Table 4: Descriptive statistics of the EOPP sample.

Variable	Mean	Std.dev.
Number of applicants	9.69	18.38
Number of interviews	5.70	7.94
Number of offers	1.11	0.50
Hours spent on screening	11.01	15.85
Fraction of firms hiring within 30 days	0.884	0.320

are overrepresented. Moreover, the pilot sites are disproportionally concentrated in Gulf Coast cities and underrepresent cities in the Northeast of the US. Further, the data set does not include workers in government and non-profit organizations. The probability for a firm in one of the sites to be included in the survey depended on its size and location and varied between 0.006 for the smallest establishments to close to 1 for establishments with more than 200 employees (see Barron et al., 1985, for more details). The data set contains sample weights to account for the heterogeneity in the sampling probability, which I use throughout.[62]

Data and Sample. I only utilize the 1982 data in this paper, which contains detailed information on recruitment process for the last hire, conditional on the hiring taking place between January 1980 and September 1981. For example, the data reports 1) the number of applications the firm received; 2) the number of interviews the firm conducted; 3) the number of job offers the firm made; 4) the wage the firm paid to the worker it hired; 5) the amount of time the firm spent screening applicants; 6) the vacancy duration; and 7) some characteristics of the hire. I restrict the sample by omitting observations with missing or unreliable values. This results in a sample of 1493 observations. Table 4 presents means and standard deviations for some of the key variables.

C.2 Derivations

Job Destruction and Matching. Using the subscript t to indicate time, unemployment evolves according to $u_{t+1} = u_t (1 - \Psi_t) + u^s_{t+1}$, where $u^s_{t+1} \equiv (1 - u_t)\, \delta\, (1 - \Psi_{t+1})$ denotes the number of short-term unemployed workers at time $t+1$, i.e. the number of workers who were not unemployed yet at time t. Using data from the Current Population Survey, Shimer (2005b, 2012) constructs time series for both u_t and u^s_t. These can be used to calculate the workers' job-finding probability Ψ_{t+1} and the job destruction rate δ_t according to

$$\Psi_{t+1} = 1 - \frac{u_{t+1} - u^s_{t+1}}{u_t} \tag{32}$$

and

$$\delta_t = \frac{u^s_{t+1}}{1 - u_t} \frac{u_t}{u_{t+1} - u^s_{t+1}},$$

[62] I thank Jason Faberman for code which corrects the weights for the non-response in the 1982 survey.

respectively. After averaging over the relevant time interval and taking into account the age structure of the sample, I find $\Psi = 0.412$ and $\delta = 0.059$.

Unemployment and Searchers. Steady state unemployment u follows from equating outflow, $u\Psi$, to inflow, $(1-u)\,\delta\,(1-\Psi)$. This implies

$$u = \frac{\delta\,(1-\Psi)}{\Psi + \delta\,(1-\Psi)} = 0.076.$$

The number of searchers is equal to $s = u + (1-u)\,\delta = 0.130$.

Number of Interviews, Conditional on Hiring. Let v_j^* denote the mass of firms posting equilibrium contract c_j^* for all $j \in \{1,\ldots,A\}$ and let n_I denote the number of interviews that a firm conducts. Applying Bayes' Rule twice then implies that the expected number of interviews conditional on hiring equals

$$\begin{aligned}
\mathbb{E}\left[n_I|\text{hire}\right] &= \frac{\sum_{j=1}^{A}\sum_{n=1}^{\infty} n\mathbb{P}\left[n_I = n|\text{hire}, c_j^*\right]\mathbb{P}\left[\text{hire}|c_j^*\right] v_j^*}{\sum_{j=1}^{A} v_j^*\mathbb{P}\left[\text{hire}|c_j^*\right]} \\
&= \frac{\sum_{j=1}^{A} v_j^* \sum_{n=1}^{\infty} n\mathbb{P}\left[\text{hire}|n_I = n, c_j^*\right]\mathbb{P}\left[n_I = n|c_j^*\right]}{\sum_{j=1}^{A} v_j^*\mathbb{P}\left[\text{hire}|c_j^*\right]}.
\end{aligned}$$

Note that $\mathbb{P}\left[\text{hire}|n_I = n, c\right]$ and $\mathbb{P}\left[n_I = n|c\right]$ were provided in the proof of proposition 1 and $\mathbb{P}\left[\text{hire}|c\right]$ equals $\eta\left(\underline{x}; c\right)$.

Number of Interviews. The (unconditional) expected number of interviews per firm equals

$$\mathbb{E}\left[n_I\right] = \frac{\sum_{j=1}^{A}\sum_{n=1}^{\infty} n\mathbb{P}\left[n_I = n|c_j^*\right] v_j^*}{\sum_{j=1}^{A} v_j^*},$$

where $\mathbb{P}\left[n_I = n|c\right]$ is again provided in the proof of proposition 1. Some algebra gives

$$\sum_{n=1}^{\infty} n\mathbb{P}\left[n_I = n|c\right] = (r+1)\left(1 - e^{-\frac{q\lambda(c)}{r+1}}\right) \leq r+1.$$

Number of Applications, Conditional on Hiring. In a similar fashion, the expected number of applicants n_A conditional on hiring equals

$$\mathbb{E}\left[n_A|\text{hire}\right] = \frac{\sum_{j=1}^{A} v_j^* \sum_{n=1}^{\infty} n\mathbb{P}\left[\text{hire}|n_A = n, c_j^*\right]\mathbb{P}\left[n_A = n|c_j^*\right]}{\sum_{j=1}^{A} v_j^*\mathbb{P}\left[\text{hire}|c_j^*\right]}$$

$$= \frac{\sum_{j=1}^{A} v_j^* \sum_{n=1}^{\infty} n \sum_{i=1}^{n} \mathbb{P}\left[\text{hire}|n_I = i, c_j^*\right] \mathbb{P}\left[n_I = i, n_A = n|c_j^*\right]}{\sum_{j=1}^{A} v_j^* \mathbb{P}\left[\text{hire}|c_j^*\right]}.$$

To calculate $\mathbb{P}[n_I = i, n_A = n|c]$, let n_Q and n_R denote the firm's number of qualified applicants and number of potential interviews, respectively. Then

$$\mathbb{P}[n_I = i, n_A = n|c] = \mathbb{P}[n_I = i|n_A = n, c]\,\mathbb{P}[n_A = n|c],$$

where $\mathbb{P}[n_A = n|c] = e^{-\lambda(c)}\frac{[\lambda(c)]^n}{n!}$ and

$$\begin{aligned}
\mathbb{P}[n_I = i|n_A = n, c] &= \mathbb{P}[n_Q = i, n_R \geq i|n_A = n, c] + \mathbb{P}[n_Q > i, n_R = i|n_A = n, c] \\
&= \left(\frac{r}{r+1}\right)^{i-1}\left[\binom{n}{i} q^i (1-q)^{n-i} + \sum_{m=i+1}^{n} \binom{n}{m} q^m (1-q)^{n-m} \frac{1}{r+1}\right].
\end{aligned}$$

Recruiting Cost, Conditional on Hiring. A firm posting a contract c spends $k_R r$ on recruiting. Assume that a year consists of 50 weeks of 5 days of 8 productive hours and let $x^{\mathbb{E}}(c)$ denote the average match quality given c. Allowing, as in Hagedorn and Manovskii (2008) and Silva and Toledo (2009), for the fact that interviewing is done by managers who earn up to 50% higher wages, the time cost of recruiting can then be calculated as

$$T(c) = \frac{2000}{12}\frac{2}{3}\frac{k_R r}{x^{\mathbb{E}}(c)}.$$

Then, the expected time spent on recruiting conditional on hiring equals

$$\mathbb{E}[T|\text{hire}] = \frac{\sum_{j=1}^{A} v_j^* \mathbb{P}\left[\text{hire}|c_j^*\right] T\left(c_j^*\right)}{\sum_{j=1}^{A} v_j^* \mathbb{P}\left[\text{hire}|c_j^*\right]}.$$

Number of Job Offers. The expected number of job offers n_O per firm equals

$$\mathbb{E}[n_O] = \frac{\sum_{j=1}^{A} \sum_{n=1}^{\infty} n\mathbb{P}\left[n_O = n|c_j^*\right] v_j^*}{\sum_{j=1}^{A} v_j^*},$$

where aggregate consistency requires $\sum_{n=1}^{\infty} n\mathbb{P}[n_O = n|c] = \lambda(c)\,\psi(c)$.

D Additional Results

D.1 Observability of Recruiting Intensity

Throughout the analysis, I have assumed that workers can observe the recruiting intensity r of each firm. The fact that firms typically do not advertise recruiting intensities in real life raises the question whether alternatives are possible. To see that this is the case, note that workers do not care about a firm's recruiting intensity r per se. Instead, they care about the probability ψ of getting a job offer. It seems reasonable that job seekers possess some information about this probability in real life, even before making application decisions. What matters in the model is whether the information that a worker observes is sufficient for him to deduce ψ. Assuming that he observes r (in addition to $\underline{x}$ and w) is an analytically convenient way to guarantee that this is the case, but is not crucial. That is, there exists other pieces of information which the worker can observe instead, such that the results remain unchanged. For example, the following proposition establishes that this is the case for the expected productivity $x^{\mathbb{E}}$ of the worker that the firm will hire, i.e.,

$$x^{\mathbb{E}}(c) = \frac{-\int_{\underline{x}}^{\infty} x \, d\eta(x; c)}{\eta(\underline{x}; c)}.$$

Proposition 7. *The results in this paper remain remain unchanged if workers observe $x^{\mathbb{E}}(c)$ instead of r for each firm.*

Proof. In order to obtain the directed search equilibrium, the information that a firm provides must allow a worker to infer the firm's queue λ. If the worker observes $c = (\underline{x}, r, w)$, then he can infer λ immediately from the equilibrium payoff. This is no longer the case if r is unobserved, since various combinations of λ and r imply the same payoff given $\underline{x}$ and w. Since the expected payoff is increasing in r and decreasing in λ, the relation between these two variables is positive.

To prove the lemma, it is then sufficient to show that only one of these combinations will imply an expected productivity equal to $x^{\mathbb{E}}$. To show that this is the case, I prove that a constant expected productivity describes a negative relationship between λ and r, such that only one point of intersection between the two curves exists. Using integration by parts, $x^{\mathbb{E}}$ can be written as

$$x^{\mathbb{E}} = \underline{x} + \int_{\underline{x}}^{\infty} \frac{\eta(x; r, \lambda, \theta)}{\eta(\underline{x}; r, \lambda, \theta)} \, dx.$$

Omitting arguments to simplify notation, some tedious algebra yields

$$\frac{\partial^2}{\partial\lambda\partial x} \log\eta = e^{-\kappa} \frac{\kappa - 1 + e^{-\kappa}}{(1 - e^{-\kappa})^2} \frac{r}{r+1} Q' > 0$$

and

$$\frac{\partial^2}{\partial r\partial x} \log\eta = \frac{\left((1 - e^{-\kappa})^2 - e^{-\kappa}\kappa^2\right) \kappa_x \kappa_r - (1 - e^{-\kappa})\, \kappa \left(1 - e^{-\kappa} - \kappa e^{-\kappa}\right) \kappa_{rx}}{(1 - e^{-\kappa})^2 \kappa^2} > 0.$$

Consequently, $\eta_\lambda(x; r, \lambda, \theta) > \eta_\lambda(\underline{x}; r, \lambda, \theta)$ and $\eta_r(x; r, \lambda, \theta) > \eta_r(\underline{x}; r, \lambda, \theta)$ for all $x > \underline{x}$. Hence, $\frac{\partial x^{\mathbb{E}}}{\partial\lambda} > 0$ and $\frac{\partial x^{\mathbb{E}}}{\partial r} > 0$, after which the Implicit Function Theorem yields the desired result. $\square$

The idea that firms communicate the type of worker that they expect to hire should not seem unrealistic. Casual observation of job ads on CareerBuilder.com suggests that the vast majority of them contains statements on the characteristics that a successful applicant is expected to have.[63]

[63] See Marinescu and Wolthoff (2015) for a detailed analysis of job ads on CareerBuilder.com.

D.2 Constrained Efficiency

A traditional concern in much of the search literature is whether the market equilibrium is constrained efficient. To answer this question, consider the problem of a social planner who chooses workers' search intensities and application portfolios as well as firms' entry, recruiting intensities, and hiring standards to maximize net social surplus, subject to the frictions of the environment. Proposition 8 analyzes these decisions for $A = 1$ and establishes that the equilibrium described in proposition 2 of the main text decentralizes the planner's solution, under the standard condition that the component of h representing unemployment benefits must equal zero.

Proposition 8. *For $A = 1$, the unique equilibrium is constrained efficient (in the absence of unemployment benefits).*

Proof. The planner aims to maximize the expected discounted value of future output. Because the matching function exhibits constant returns to scale in searchers and vacancies, this value is linear in the number of searchers s (see e.g. Shimer, 2004). The planner's problem is therefore equivalent to maximizing the expected discounted social value of an individual searcher. Denote this value by S^P and the denote the expected discounted social value of a match with productivity x by $M^P(x)$. That is, analogous to (10), $M^P(x)$ equals

$$M^P(x) = x + y + \beta\left((1-\delta) M^P(x) + \delta S^P\right).$$

The planner chooses the number $\frac{1}{\lambda}$ of vacancies that must be created for the searcher as well as a hiring standard $\underline{x}$ and a recruiting intensity r for each of these vacancies.[64] If the searcher matches, a value $M^P(x)$ is generated. Otherwise, the searcher produces h during unemployment and can search again in the next period. Hence, S^P equals

$$S^P = \max_{\underline{x},r,\lambda} \frac{1}{\lambda}\left[\int_{\underline{x}}^{\infty} M^P(x)\, d\eta(x; r, \lambda, 1) - k_R r - k_V\right] + (1 - \psi(\underline{x}, r, \lambda, 1))\left[h + \beta S^P\right]. \tag{33}$$

The first-order condition of (33) with respect to $\underline{x}$ reveals that the planner's hiring standard x^P satisfies

$$M\left(\underline{x}^P\right) = h + \beta S^P. \tag{34}$$

That is, the planner will only create matches for which the associated value exceeds the searcher's social value of unemployment. Note that the optimal threshold is independent of the planner's solution for the queue or recruiting intensity. Evaluating (33) in the optimal $\underline{x}^P$ yields, after integration by parts,

$$S^P = \max_{r,\lambda} \frac{1}{\lambda}\left[\frac{1}{1-\beta(1-\delta)} \int_{\underline{x}^P}^{\infty} \eta(x; r, \lambda, 1)\, dx - k_R r - k_V\right] + h + \beta S^P. \tag{35}$$

The queue λ^P and recruiting intensity r^P that the planner chooses must satisfy the first-order

[64] The planner's choice of search intensity trivially equals $\alpha^P = 0$ and is therefore omitted.

condition of (35) with respect to λ, i.e.

$$\frac{1}{1-\beta\left(1-\delta\right)}\int_{\underline{x}^P}^{\infty}\left[\eta\left(x;r^P,\lambda^P,1\right)-\lambda^P\eta_\lambda\left(x;r^P,\lambda^P,1\right)\right]\,dx-k_Rr^P-k_V=0, \tag{36}$$

and the first-order condition with respect to r, i.e.

$$\frac{1}{1-\beta\left(1-\delta\right)}\int_{\underline{x}^P}^{\infty}\eta_r\left(x;r^P,\lambda^P,1\right)\,dx-k_R\leq 0 \tag{37}$$

for $r^P\geq 0$, with complementary slackness.

Evaluating (35) in (34) and (36) gives

$$S^P=\frac{1}{1-\beta\left(1-\delta\right)}\int_{\underline{x}}^{\infty}\eta_\lambda\left(x;r,\lambda,1\right)\,dx+h+\beta S^P. \tag{38}$$

Clearly, the system of equations (34) to (38) is isomorphic to the system characterizing the market equilibrium described in the proof of proposition 2. Hence, a unique solution to the planner's problem exists and this solution corresponds to the market equilibrium, $\underline{x}^P=\underline{x}^*$, $r^P=r_1^*$, and $\lambda^P=\lambda_1^*$. That is, the market equilibrium is constrained efficient. □

The intuition for this result is the same as in other directed search models with one application in which the equilibrium is efficient (e.g. Moen, 1997; Shimer, 2005a; Menzio and Shi, 2011): since a firm takes workers' equilibrium payoffs as given, it is the residual claimant on any additional surplus it creates; this provides the firm with an incentive to post a contract that maximizes surplus, as long as there exists such a contract which simultaneously allows for this surplus to be divided in an arbitrary way to provide workers with the required payoff.[65] Hence, proposition 8 can be interpreted as establishing that the contract space $\mathcal{C}$ is sufficiently rich to make this possible for $A=1$.[66]

Efficiency does not extend to the case in which workers send multiple applications, $A>1$. The reason is straightforward: workers base their acceptance decisions on the terms of trade w, which may cause them to accept a less productive match over a more productive match.[67] However, it is worth emphasizing that this is not the only reason for inefficiency for large regions of the parameter space. To see this, consider a productivity distribution $Q\left(x\right)$ which is degenerate, such that this particular source of inefficiency is absent. For this environment, we know from the work by Galenianos and Kircher (2009) and Kircher (2009) that there exists a second potential inefficiency. In particular, a firm is only interested in applicants that will end up accepting their job offers. Applicants that reject the firm's job offer may crowd out these more desirable candidates, which is a negative externality that needs to be priced for constrained efficiency to prevail. However, a wage payment is not able

[65] Eeckhout and Kircher (2010) call contracts that satisfy the latter requirement "payoff-complete." Efficiency generally requires that workers are paid their marginal contribution to surplus. See Moen (1997), Kircher (2009), and Lester et al. (2015, 2017) for a detailed discussion of efficiency in directed search models.

[66] In fact, the contract space $\mathcal{C}$ is richer than required: since firms choose hiring standards which are optimal ex post, they not need to commit to them ex ante.

[67] In addition, firms posting $c_2^*,\ldots c_A^*$ set hiring standards that are inefficiently high. However, rather than a separate source of inefficiency, this is the optimal way to reduce workers' inefficient acceptance decisions.

to fulfill this role, since applicants that turn down the job offer never match with the firm. Instead, firms would likely need to extend their contracts with application fees, to be paid by all applicants.[68] The only time this source of inefficiency is absent is when firms interview *all* applicants ($r \to \infty$), which in my model requires $k_R = 0$.[69]

[68]Mathematically, efficiency along this dimension requires that the firm's hiring probability η depends on λ only through μ, as discussed by Kircher (2009). This is the case if and only if the distribution of the number of interviews satisfies the *invariance* property of Lester et al. (2015). See their paper for a detailed discussion of how application fees can improve welfare in a related environment if and only if invariance is violated.

[69]Gautier and Holzner (2014) point out that even in this case a planner can further improve welfare if we allow him to take into account the structure of the network: a firm with a single candidate should get priority in hiring this worker over a firm with multiple candidates. Decentralization of this idea requires ex-post competition between firms or at least contracts with payments conditional on a worker's entire set of job offers.

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