Statistical Discrimination and Duration Dependence in the Job Finding Rate*

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Abstract

Recent evidence from resume audit studies shows that employers statistically discriminate against the long-term unemployed (Kroft et al. (2013)). To map this evidence into its effect on the job-finding rate and long-term unemployment, we propose a search model of the labor market where dynamic selection on unobservables endogenously generates such discrimination. We estimate the framework targeting the empirical evidence on statistical discrimination and duration dependence in the job finding rate. We show analytically and quantitatively that discrimination has only small effects on the job finding rate and contributes little to long-term unemployment. Firms discriminate to avoid costly interviews with workers they would not hire ex-post. But since they would not hire them ex-post, discrimination at the interview stage has little consequences for job-finding rates. This provides an important qualification to recent evidence on employer discrimination from field experiments.

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1 Introduction

A string of recent papers has shown that firms use unemployment duration as a tool to aid in interview decisions. For example, using a large-scale resume audit study, Kroft, Lange, and Notowidigdo (2013) document that callback rates for interviews decline significantly with unemployment duration. Ceteris paribus, they find that a worker unemployed for 8 months is 45 percent less likely to receive a callback for an interview than an observationally equivalent newly unemployed worker. Ghayad (2013), Eriksson and Rooth (2011), and Oberholzer-Gee (2008) all document similar employer behavior.

Unfortunately, the aforementioned resume audit studies do not allow us to observe who ultimately gets hired beyond this first step in the hiring process. Similarly, we can never observe whether or not rejected workers might have been hired had they been interviewed. It is therefore impossible to conclude how such discrimination affects the job finding rate, long-term unemployment, and the overall unemployment level. In this paper, we develop a model of the labor market that gives rise to employer discrimination at the interview stage, consistent with these audit studies. The model allows us to tie the evidence on discrimination to real outcomes in the labor market, and to asses the importance of the screening mechanism in generating long-term unemployment.

We begin from the observation in Kroft et al. (2013) that duration dependence in callbacks becomes stronger in tighter labor markets, suggesting that such employer behavior is statistical in nature and responds to beliefs about the pool of workers in unemployment. Thus, we propose a model of the labor market in which firms endogenously discriminate among applicants because their duration becomes an informative signal about their anticipated quality. If better workers find jobs at faster rates than less qualified workers, the latter will be over-represented in the unemployment pool at longer durations due mechanically to dynamic sorting.[1] Consequently, if interviewing workers is costly, firms condition their inter-

[1] We later define precisely what is meant by "better" and "less-qualified" workers.

view decisions on unemployment duration to better predict the quality of the applicants they face and economize on interview costs. In this setup, discrimination arises endogenously as a response to dynamic sorting on unobservables, rather than through pure taste biases or through self-fulfilling prophecies.

Inevitably - because the employer discrimination is statistical - some workers are not interviewed for jobs that may have been a good match, and some workers are interviewed that will ultimately not be hired. In other words, the equilibrium will feature both false positives and false negatives. Accordingly, some "true" duration dependence in the job-finding rate will arise as workers are denied job opportunities simply because of their unemployment duration. A direct corollary is that at least some equilibrium unemployment is a result of the discrimination. This seems to be what leads many to believe that discriminatory employer behavior such as that which is documented in resume audit studies may be responsible for generating long-term unemployment. Our goal, then, is to quantify the extent to which this inference is valid.

To this end, we estimate the underlying distribution of unobserved heterogeneity in our model that is consistent with the empirical hazard in the callback rate detected by Kroft et al. (2013), as well as the unconditional empirical job-finding probability by unemployment duration from the Current Population Survey (CPS). The estimated model allows us to condition on unobservables and ask how an individual's job-finding rate declines with duration, and how many long-term unemployed workers have been "mistakenly" screened. In this sense, our model estimation can be seen as an alternative to the approaches taken in the micro-empirical literature that attempts to separately identify state dependence from unobserved heterogeneity.

We sample the distribution of long-term unemployed workers and ask how the job-finding rate of this representative group has changed since exiting employment. We find that, once we control for unobserved heterogeneity, true duration dependence in the job-finding rate nearly disappears. In other words, the representative long-term unemployed worker experi-

ences almost no decline in her job-finding probability as a result of employer discrimination as her unemployment tenure increases. The intuition is straightforward. Since discrimination is statistical, if firms discriminate it is because they anticipate being unable to form viable matches with most long-term unemployed workers. This leads firms to turn down these workers at the resume stage rather than after an interview has been conducted. Consequently, this has no real impact on a job-seeker's counterfactual job finding rate. Again, a direct corollary is that discrimination of this kind generates little long-term unemployment. While highly qualified workers would be affected by discrimination in callbacks at longer unemployment durations, they are rarely unemployed long enough to experience that discrimination in the first place; or, if they were, we could not rationalize the empirical amount of discrimination documented in the field experiments.

To provide some intuition for this result, we show analytically why discrimination will has minimal impact on true duration dependence in the job-finding rate in our framework. The job finding rate is a function of the intersection between the set of firms willing to hire a worker, and the set of firms willing to interview a worker. The only workers affected by employer discrimination are workers who experience discrimination by firms that are in their hiring set. We relate the firm's decision to discriminate to the probability it will meet a positive-surplus unemployed worker. The probability a worker is qualified is (approximately) bounded by the value of interview costs relative to the present discounted value of the match, conditional on a match being formed. If a firm opts to discriminate, the choice reveals that the costs of interviewing are too large relative to the expected gain from inviting a long-term unemployed worker for an interview. Since interview costs are small and employment relationships last long, in equilibrium this implies that the majority of workers who are screened would not have formed feasible matches with discriminating firms.

Still, if one were to conduct a resume audit study in an economy simulated by our model, one would find large amounts of discrimination through the lens of a field experiment. Our model empirical decline in the callback rate as documented by the audit studies applies

to the most well-qualified workers who typically remain unemployed for shorter periods of time, rarely long enough to experience such discrimination. In turn, less-qualified workers are unaffected by this firm behavior because discriminating firms are not in their hiring set to begin with.

The rest of the paper proceeds as follows. The next section discusses related literature. In Section 3 we describe the model. In Section 4, we estimate the model using indirect inference, and in Section 5 we use the estimated model to quantify the real effects of discrimination in the labor market, both overall and for various unemployment durations. Finally, Section 7 concludes.

2 Literature

There are other papers that generate endogenous screening on unemployment duration as we do. For example, Lockwood (1991), Fernandez-Blanco and Preugschat (2015), and Doppelt (2015) deliver endogenous employer screening on unemployment duration. While our mechanism is much the same as theirs, our focus is instead on how such discrimination can impact duration dependence in the job-finding rate and consequently the level of unemployment, a question that to date has not been addressed. Ours is the first to quantitatively match micro-evidence on employer discrimination and quantify its real effects in the labor market. Our setting is particularly well suited for this endeavor since our setup is simple enough to include two-sided heterogeneity.

Blanchard and Diamond (1994) analyze how ranking affects equilibrium labor market outcomes. In their model, duration dependence in job-finding probabilities arises because of assumptions on the hiring technology - firms are assumed to rank the resumes they receive on unemployment duration and choose the worker with the lowest duration. In our model, duration dependence arises endogenously due to information externalities and optimizing behavior on the part of employers. This modeling assumption is key because revealed pref-

erence arguments allow us to quantify how discrimination affects duration dependence and unemployment. In addition, our mechanism is consistent with the results found in Kroft et. al (2013) regarding variation in callback rates by tight versus weak labor markets. The information content of unemployment duration is stronger in tight labor markets when meetings between workers and firms occur frequently and unemployment duration is extremely informative.

Coate and Loury (1993), building on earlier work by Phelps (1972) and Arrow (1971), model endogenous discrimination in the labor market, focusing instead on discrimination against two groups such as blacks and whites. The key difference is that in our work, discrimination arises because of dynamic sorting, whereas in their work, discrimination is a feature of one possible equilibria where employer beliefs are "self-fulfilled" through worker investment behavior. Here, where the underlying dynamic sorting that leads to group differences is mechanical, there is no equilibrium in which firms do not discriminate.

Finally, because we estimate unobserved heterogeneity and ask how this affects the aggregate job-finding rate, our work is strongly linked to the micro empirical literature which seeks to separately identify state dependence from unobserved heterogeneity in job-finding probabilities.[2] We believe our approach has several advantages. First, we formulate the job-finding hazard using a structural model whose underlying parameters are objects such as the separation rate which are readily observable in micro data. Second, the model provides a tight link between the underlying unobserved heterogeneity and the baseline hazard. That is, the theory suggests that the baseline hazard and distribution of unobserved heterogeneity are not independent from one another. Finally, we use evidence on the callback rate to help identify the underlying unobserved heterogeneity. We think this evidence is useful because it embodies the beliefs firms have about the average quality of workers they face in the unemployment pool at various durations. Since the quality of workers is generally unobservable to econometricians, it is a useful statistics that has thus far not been exploited in this sort of

[2]See, for example, Elbers and Ridder (1982), Heckman and Singer (1984a), and Heckman and Singer (1984b).

exercise.[3] We show that, in our framework, state-dependence in the job-finding probability depends on worker quality, and is not necessarily proportional, a shortcoming of the mixed proportional hazards model that has already been pointed out by others.[4]

3 Model

3.1 Environment

The economy consists of a continuum of infinitely lived workers indexed by their type $x \in [\underline{x}, \bar{x}]$ and, if unemployed, by their unemployment duration $\tau \in [0, \infty]$. The exogenous distribution of worker types is given by $l(x)$ and the total measure of workers in the economy is such that $\int l(x)dx = 1$. We think of x as representing skills that are unobservable on a resume, and are (at least partially) revealed to an employer during an interview.[5] Workers search for jobs by sending out one resume per period, and have access to home production technology b.

There is a continuum of firms indexed by their type $y \in [\underline{y}, \bar{y}]$, with an exogenous distribution $v(y)$ of each type. Firms y have access to a production technology $p(x, y)$ when matched with a type x worker, and matches separate with exogenous probability δ. We assume that:

1. $p(x, y)$ is weakly increasing for $x \in [\underline{x}, \bar{x}]$, and strictly increasing over some interval $\tilde{X} \subseteq [\underline{x}, \bar{x}]$

2. $\exists \;\; y \in [\underline{y}, \bar{y}] \;\; \text{s.t.} \;\; p(\underline{x}, y) - b < 0$ and

3. $\exists \;\; y \in [\underline{y}, \bar{y}] \;\; \text{s.t.} \;\; p(\underline{x}, y) > b$

[3] Of course, it comes with the drawback that we must now model unobserved firm heterogeneity. We return to this point in the estimation of our model.

[4] See van den Berg (2001) and more recently in Kroft et al. (2013).

[5] As Arrow (1973) describes, we think of "more subtle types of personal deprivation and deferment of gratification which lead to the habits and action of thought that favor good performance in skilled jobs, steadiness, punctuality, responsiveness, and initiative."



Figure 1: Model Timeline

The first assumption will ensure that dynamic selection will be present in the model, as we will later show more formally. That is, there should on average be returns to interviewing workers that are of higher types. The second assumption ensures that firms care about such dynamic selection in their hiring decision, i.e. that there are some firms that do not want to hire low type workers. The last assumption ensures that the job-finding rate for the lowest type workers remains positive even if their unemployment duration tends to infinity.

The joint distribution in unemployment of duration and skill $u(x, \tau)$ is endogenous and depends on the hiring decisions of firms. Unemployed workers contact firms at an exogenous rate λ. Upon meeting one another, which we refer to as the *resume stage* or *interview stage*, firms cannot observe the worker's type x, but can readily infer the worker's unemployment duration τ from their resume. Thus, x represents heterogeneity among workers that is observable after an interview, but unobservable at the resume stage. For simplicity, we assume that information about the worker's type is fully revealed to the firm after the interview.[6] If there is any information contained in duration, firms can form expectations about the worker's type conditional on the observed duration. They can choose to reject the worker without an interview, or they can pay a cost κ to interview the worker and learn the worker's type x with certainty. If the firm chooses to interview the worker and thus learns their type, they then decide on whether or not to consummate the match. We refer to this as the *hiring stage*. The timing of the model is summarized graphically in Figure 1.

[6] We argue that, as long as the interview reveals some information about x, unemployment duration will be a (noisy) signal. With a noisy rather than perfect signal, we would estimate larger amounts of heterogeneity in order to rationalize the empirical degree of employer discrimination, leaving our quantitative conclusions about the consequences of discrimination for the job-finding rate unchanged. We discuss this point in more detail in the appendix.

3.2 Workers

Consider a type x worker who is unemployed with duration τ. She earns the flow value of unemployment b, and expects her resume to reach some firm y with probability $\lambda \cdot v(y)$. The only way she will become employed is if the firm is willing to interview her *and* hire her conditional on the outcome of the interview (the revelation of her type). The value of unemployment to this type (x, τ) worker is given by:

$$\begin{aligned} U(x,\tau) = b + \beta\lambda \int_{I(\tau)\cap H(x,\tau)} & W(x,y,w(x,y,\tau))v(y)dy \\ & + \beta[1 - \lambda \int_{I(\tau)\cap H(x,\tau)} v(y)dy]U(x,\tau+1) \end{aligned} \tag{3.1}$$

where $W(x, y, w(x, y, \tau))$ is the value of being employed at a type y firm with wage $w(x, y, \tau)$, $I(\tau)$ is the set of firms y that are willing to interview a type τ worker, and $H(x, \tau)$ is the set of firms willing to hire a type (x, τ) worker which we will specify later. The value of employment can be written as:

$$W(x,y,w(x,y,\tau)) = w(x,y,\tau) + \beta(1-\delta)W(x,y,w(x,y,\tau)) + \beta\delta U(x,0) \tag{3.2}$$

The worker receives a wage $w(x, y, \tau)$, and with probability $1-\delta$ the match remains intact and with probability δ the match separates and the worker becomes unemployed with duration $\tau = 0$.

We assume that wages are Nash-bargained and that firms have all the bargaining power, offering workers their reservation wage. Hence, in equilibrium all employed workers earn a flow value equal to their value of leisure, $w(x, y, \tau) = b$ and wages are independent of unemployment duration. This assumption buys us a lot of tractability. In particular, all value functions remain independent of unemployment duration. While this assumption generates implausible implications for wages (i.e., re-employment wages are flat with unemployment duration), it is innocuous with regard to the center of our analysis, the consequences of

discrimination for the job finding rate. In our extension which includes search intensity as a choice variable, we assume workers receive a positive share of match surplus to rationalize the choice of search intensity and our qualitative results do not change. Therefore, for expositional purposes we present the model with this assumption present.

Since firms offer workers their reservation wage, workers will receive b whether or not they are employed, and regardless of their unemployment duration. Thus, we can write these values independent of unemployment duration:

$$U(x) = U = \frac{b}{1-\beta} \quad \forall x \in X \quad \forall \tau \in [0, \infty] \tag{3.3}$$

and

$$W(x, y) = U = \frac{b}{1-\beta} \quad \forall x \in X, y \in Y. \tag{3.4}$$

3.3 Interviewing, and Hiring

Let $J(x, y)$ be the value of a job filled by a type x worker to a type y firm:

$$J(x, y) = \frac{p(x, y) - b}{1 - \beta(1 - \delta)} \tag{3.5}$$

Since workers are held to their reservation value, this is also the joint surplus of the match.

We begin with the hiring decision. When a firm has interviewed a worker and learned her type x, he must decide whether or not to hire the worker. Only workers that deliver positive surplus to the firm will be hired. Let $H(x)$ denote the set of firms willing to hire a type x worker. This set will be defined as follows:

$$y \in H(x) \text{ iff } J(x, y) \geq 0$$

Thus, after an interview, firms hire workers which deliver positive value to the firm.

$$y \in H(x) \text{ iff } \frac{p(x,y)-b}{1-\beta(1-\delta)} \geq 0 \tag{3.6}$$

Turning to the interview decision, when a firm receives a worker's resume and does not know her type x, he forms expectations about the value he will receive from the match, conditional on the worker's duration, $\int \max\{J(x,y),0\}u(x|\tau)dx$. If this is greater than or equal to the cost of interviewing the worker, the firm pays the cost and interviews the worker. If not, the firm immediately turns down the worker. Thus, we can define the set of firms y willing to interview a worker of duration τ as:

$$y \in I(\tau) \text{ iff } \int_X \max\{J(x,y),0\}u(x|\tau)dx \geq \kappa$$

or

$$y \in I(\tau) \text{ iff } \int_X \max\left\{\frac{p(x,y)-b}{1-\beta(1-\delta)},0\right\}u(x|\tau)dx \geq \kappa \tag{3.7}$$

We emphasize here that the only way for a worker (x,τ) to get hired by a firm y when they receive her resume is for (1) firm y to be in worker (x,τ)'s interview set $I(\tau)$ and (2) firm y to be in worker (x,τ)'s hiring set $H(x)$.

3.4 Laws of Motion

At the beginning of the period, a measure $u(x,\tau)$ are unemployed type x workers with duration τ and a measure $e(x)$ are employed type x workers. Some of the viable matches exogenously separate, and some workers find a job. For the workers who do not find a job, unemployment duration increases by one period. Therefore, the stock of unemployed type-x

workers with duration τ next period is given by:

$$u'(x,\tau) = \begin{cases} \delta e(x) & \text{if } \tau = 0 \\ u(x,\tau-1)(1-\lambda \int_{I(\tau)\cap H(x,\tau)} v(y)dy) & \text{if } \tau > 0. \end{cases} \tag{3.8}$$

Anyone who separates will be unemployed with duration $\tau = 0$ and the remaining unemployed workers who do not find work all increase their duration by one period. The stock of employed type x workers is given by:

$$e'(x) = (1-\delta)e(x) + \lambda \sum_{\tau=0}^{\infty} \int_{I(\tau)\cap H(x,\tau)} u(x,\tau)v(y)dy$$

3.5 Equilibrium

A steady state equilibrium of this economy is a triple $\{H, I, u\}$ where:

1. the interview set I is optimal given u, H so that it satisfies 3.7,
2. the hiring set H is optimal, so that it satisfies 3.6, and
3. the joint distribution of types and duration in unemployment $u(x,\tau)$ satisfies 3.8 given H and I.

Given our assumptions on the production function, we can characterize the nature of the hiring and interview sets. Both sets will be defined by a cutoff rule. Since output is increasing in the worker's type, a firm is willing to hire any worker that delivers positive surplus. We then show that the job-finding rate increases in worker type, implying that the unemployment distribution of types at τ first order stochastically dominates the distribution at $\tau + 1$ $\forall \tau \in [0\infty]$. Since this implies expected surplus is declining with unemployment duration, we show that firms use cutoff strategies in their interview decisions as well. Finally, we show that the equilibrium will exhibit discrimination, i.e. that the set of firms willing to interview duration τ workers is weakly decreasing with τ.

Proposition 1. *The hiring decision for a firm y is a cutoff rule strategy where they hire workers of type $x \geq x^\star(y)$ and do not hire workers $x < x^\star(y)$ with $x^\star(y)$ solving 3.6 with equality.*

Thus, for any $x_1 < x_2 \in X$, $H(x_1) \subseteq H(x_2)$, with $H(x_1) \subset H(x_2)$ for some $x_1, x_2 \in [\underline{x}, \bar{x}]$, expected surplus is strictly decreasing in unemployment duration, and firms use cutoff strategies for interviews, with $z^\star(y)$ satisfying 3.7 with equality. The equilibrium thus exhibits discrimination, i.e. $I(\tau + 1) \subset I(\tau)$ for some $\tau > 0$.

The proof for Proposition 1 can be found in the appendix.

4 Estimation

In this section, we calibrate the model to a weekly frequency, and aggregate up to a monthly frequency to match available data from the CPS.[7] We work with 100 worker types and 100 firm types, both bounded between $[1, 2]$. To begin, we fix some parameters exogenously. We set the discount rate to .999, consistent with a 5% interest rate and set the separation rate to .008 to match a monthly separation rate of $\sim 3\%$. We set unemployment benefits at .7, but intend to estimate this parameter later.

We assume the production function takes the following form:

$$p(x, y) = \begin{cases} y, & \text{if } x \geq y \\ 0, & \text{otherwise} \end{cases} \tag{4.1}$$

and check that our results are robust to the specification of the production function. However, this particular functional form ensures that the model delivers both positive assortative matching conditional on a match, and a higher probability of rejection post-interview for lower worker types. We choose the cost of an interview κ to match evidence from Silva and

[7] The estimation is still preliminary. We are in the process of estimating the model via Monte Carlo methods.

Toledo (2007) on interview costs. They find that, using the Small Business Administration Survey, on average employers spend 16 hours per hire. If there are approximately 35 working hours per week, then employers spend roughly .5 weeks per hire. In terms of output, this translates into $.5 \cdot \frac{wks}{hire} \cdot \frac{E(y)}{wks}$. Given our production function, $E(y) = 1.5$. Therefore, each employer spends roughly .75 units of output per hire. Since not every interview turns into a hire, this is an upper bound on the cost of an interview. Finally, we assume that the distribution of vacancies is $v(y) \sim U(1,2)$.[8] The set of fixed parameters is summarized in Table 1.

Parameter	Value	Source/Target/Reason
β	0.999	5% interest rate
δ	0.008	3% monthly separation rate
κ	$.5E(p(x,y))$	Silva & Toledo (2007)
b	.7	-
$v(y)$	$U(1,2)$	-

Table 1: Fixed Parameters

4.1 Estimated Parameters

Conditional on the fixed parameters, we estimate the remaining parameters using Simulated Method of Moments, and search for the remaining parameters to best fit several informative moments in the data. We assume that the unobserved heterogeneity is distributed $X \sim 1+\beta(A,B)$, and estimate the parameters A and B governing this distribution, as well as the contact rate λ. We choose the Beta distribution since it is relatively flexible and nests several interesting cases. These include uniformity in productivity ($A = B = 1$), homogeneity in productivity (the limit as A and B tend to infinity), skewness (both left and right, depending on A relative to B), and bi-modal heterogeneity ($A = B < 1$).

We target several informative moments: the job-finding rate by unemployment duration, the unemployment duration distribution, the callback rate curve, the average job-finding

[8] We suspect, though we have not proven, that this is a normalization in that what matters is the distribution of viable pairs (x, y) and not the individual distributions of x and y themselves.

rate, and the unemployment rate. Increases in the contact rate increase the average job-finding rate, but also increase the slope of the relative job-finding rate curve as not getting hired becomes a more informative signal of quality. However, the unemployment duration distribution becomes more skewed to short term unemployment since the job-finding rate is increases.[9] Increases in A and B tend to move the slopes of the relative job-finding rate and relative callback rate in the same direction. Increases in However, conditional on a choice of $v(y)$, the callback rate tells us something about the average worker type in unemployment at various durations, which in turn say something about how the underlying pool of unemployed workers changes with duration.

Since the heterogeneity we model on the worker side is unobservable, we condition on observables in the data to empirically estimate these moments. To operationalize the relative job-finding rate, we follow Kroft et al. (2014) and estimate the negative exponential relationship between the conditional job-finding probability and unemployment duration (in months) in the Current Population via weighted nonlinear least squares. That is, we estimate the following functional form for the job-finding probability relative to the job finding probability of workers who have been unemployed one month or less:

$$\frac{\bar{f}(\tau)}{\bar{f}(0)} = b_1 + (1 - b_1)\exp(-b_2 \cdot \tau) \tag{4.2}$$

controlling for various observable characteristics.[10] Figure 2 plots the raw data along with the fitted curve above (conditional and unconditional). Even conditioning on observables, the job-finding probability declines by approximately fifty percent. We find that $\{\hat{b}_1, \hat{b}_2\} = \{.407, .223\}$

Similarly, we use estimates of duration dependence in the callback rate found in Kroft et

[9]Since we work with hazards, clearly the duration distribution and the job-finding rate curve are all related.

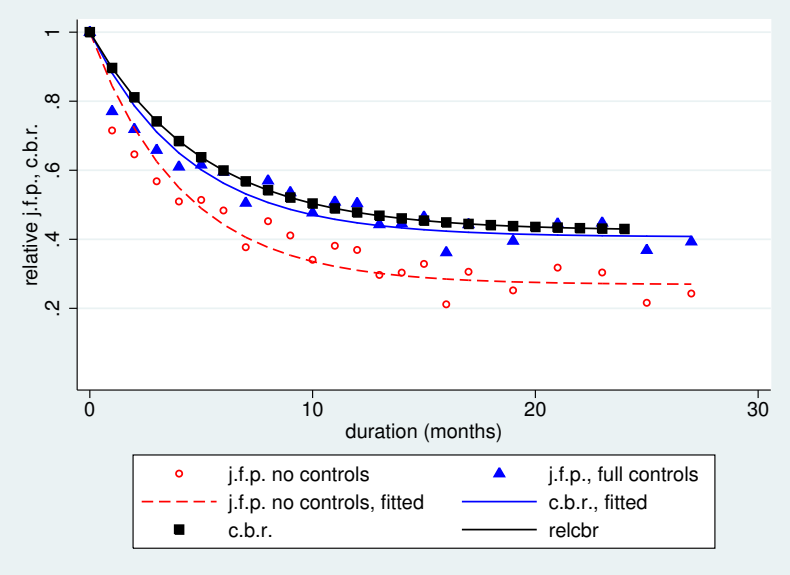
[10]Specifically, we follow Kroft et al. (2014) and control for gender, a fifth degree polynomial in age, three race dummies (white/black/other), five education category dummies, and gender interactions with all these covariates.

al. (2014). The authors use data from Kroft et al. (2013) and fit a function of the form:

$$\frac{\iota(\tau)}{\iota(0)} = a_1 + (1 - a_1) * \exp(-a_2 \cdot \tau)$$

to estimate $\{a_1, a_2\}$, where $\frac{\iota(\tau)}{\iota(0)}$ is the callback rate for an interview as a function of unemployment duration relative to the callback rate for the newly unemployed. They find that $\hat{a}_1 = .425$ and $\hat{a}_2 = .199$. We estimate the same two exponential relationships using model-generated data and include the estimated parameters as targeted moments.

Figure 2: Relative Job-Finding Probability and Callback Rates by Unemployment Duration



Notes: Source: For the job-finding rate we use pooled CPS data from 1976-present. The red dots represent the job-finding hazard at duration τ relative to the job-finding hazard for the newly unemployed. We estimate $\frac{\bar{f}(\tau)}{\bar{f}(0)} = b_1 + (1 - b_1) * \exp(-b_2 \cdot \tau)$ and find that $\{\hat{b}_1, \hat{b}_2\} = \{.357, .404\}$. We control for gender, a fifth degree polynomial in age, three race dummies (white/black/other), five education category dummies, and gender interactions with all these covariates. We take the estimated relative callback rate curve directly from Kroft et al. (2014).

4.2 Estimation Results

Our preliminary estimation suggests that $A = 6.2$ and $B = 2.47$, which represents a distribution that is slightly skewed to the left.[11]

[11] This distribution is only informative relative to the distribution of available jobs.

Table 2: *Estimated Parameters*

Parameter	Description	Estimate
A	Beta distribution	4.792
		[2.662, 6.921]
B	Beta distribution	3.133
		[1.499, 4.767]
λ	contact rate	0.193
		[0.038, 0.347]

The fit of the call back rate and job-finding rate can be found in Figure 3, and the implied distribution of unobserved heterogeneity can be found in Figure 4.

Figure 3: Estimated and Targeted Relative JFP and Relative CBR

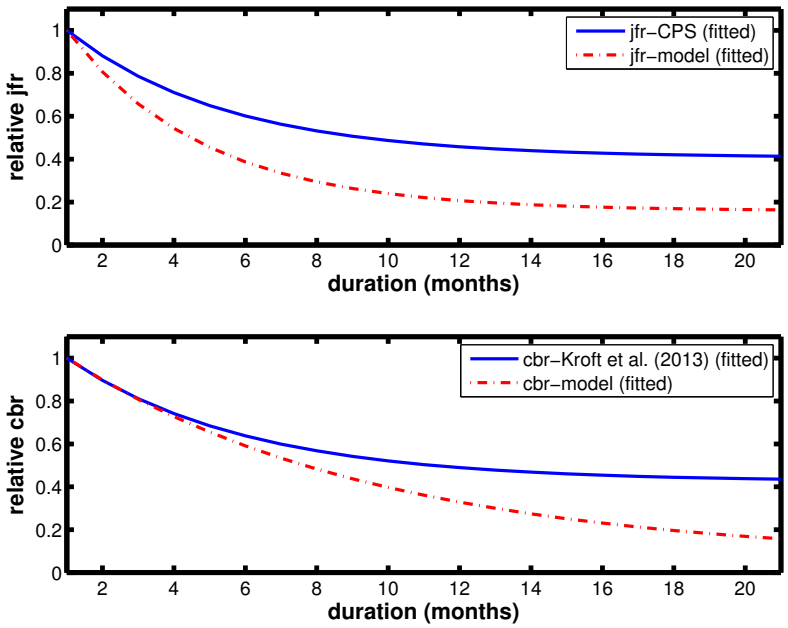
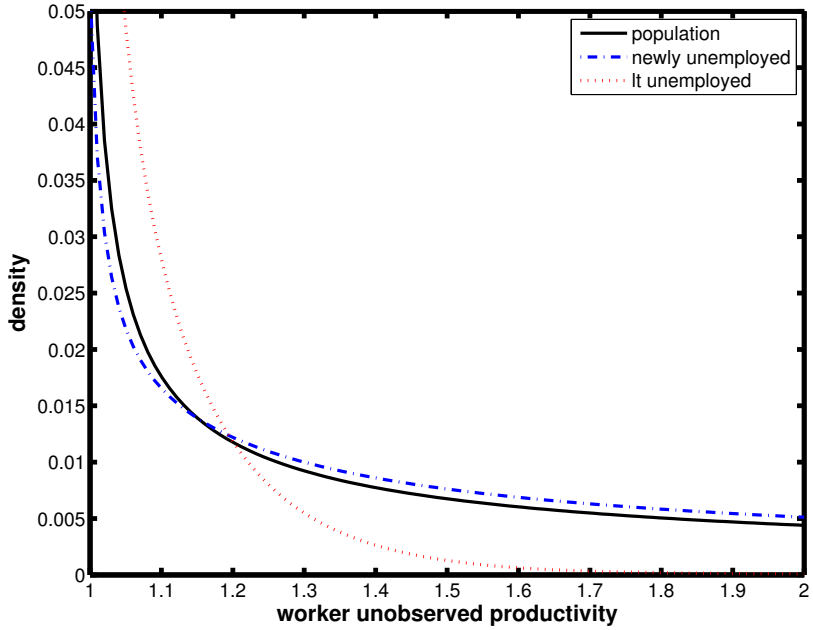
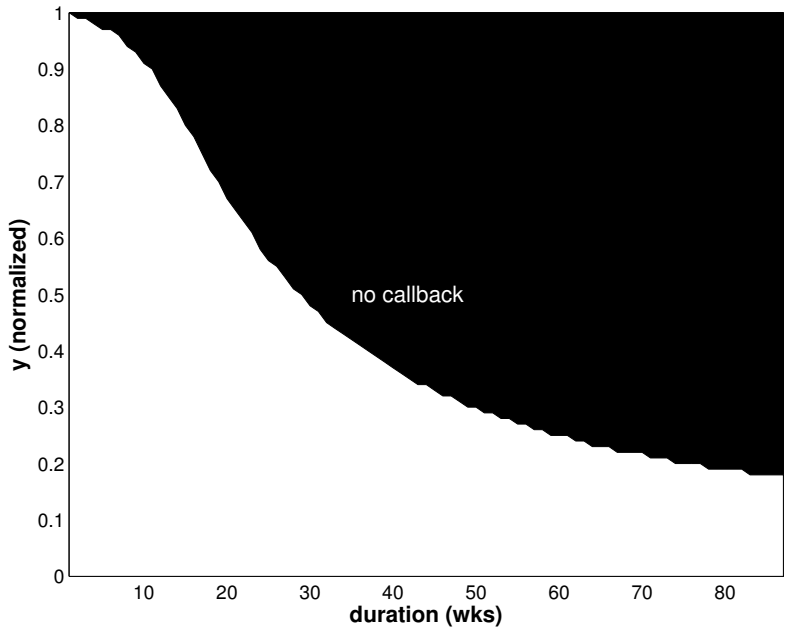


Figure 4: Estimated Distribution of Unobserved Heterogeneity



The distribution of worker types in long-term unemployment is skewed to the left compared to the distribution of the employed. This is because, by assumption, better workers have higher job-finding rates and are more likely to be employed. In response to this dynamic sorting, firms begin to discriminate. Each firm will, in general, have a different unemployment duration cutoff, which we plot in Figure 5. The lowest firm types have the highest cutoffs because they are relatively less picky regarding workers given the production function we have specified. For example, when we assume $p(x, y) = x + y$, low firm types discriminate first (i.e. at lower durations).

Figure 5: The Set of Firms Willing to Interview τ Workers, $I(\tau)$



5 The Effects of Discrimination on the Job-Finding Rate

In this section, we use the model, which has been estimated to match the empirical callback and job-finding rates, to ask how state dependence in callback rates translates into state-dependence in the job-finding rate. In our framework, the job-finding probability for a type x worker with τ periods of unemployment is given by:

$$f(x,\tau) = \lambda \int_{y \in I(\tau) \cap H(x,\tau)} v(y)dy \tag{5.1}$$

What we measure in the data, plotted in Figure 2, is the probability of finding a job at duration τ relative to the probability of finding a job for the newly unemployed conditional on observables, but unconditional on unobservables:

$$DD(\tau) = \frac{\int_x f(x,\tau)u(x,\tau)dx}{\int_x f(x,0)u(x,0)dx} \tag{5.2}$$

However, since we have estimated unobserved heterogeneity in our model, we can construct counterfactual relative job-finding probabilities that control for dynamic selection. In general, there are two possible approaches which will yield different estimates for true duration dependence. In the first, we hold the distribution of worker types fixed at its time zero counterpart, and ask how the job-finding probability evolves for this group of workers with unemployment duration:

$$TDD^0(\tau) = \frac{\int_x f(x,\tau)u(x,0)dx}{\int_x f(x,0)u(x,0)dx} \tag{5.3}$$

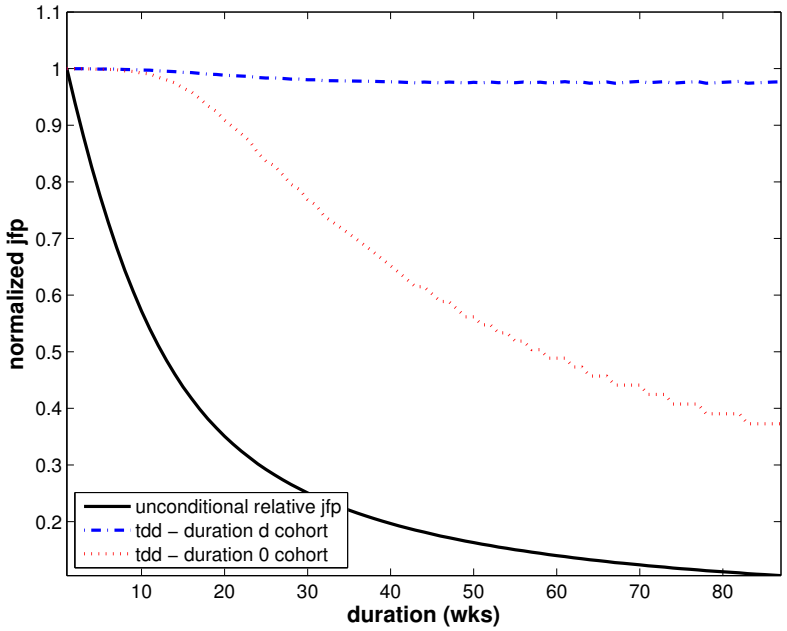
This is plotted in red in Figure 6. The figure suggests that for the representative group of newly unemployed workers, discrimination has a severe negative impact on their ability to find a job because the firms who are in their hiring set H are exactly the firms that begin to discriminate. This notion of true duration dependence reveals that discrimination adversely affects the job-finding rate for well qualified workers, should they unluckily become unemployed for long periods of time.

However, this notion of true duration dependence ignores the fact that a representative newly unemployed worker is rarely unemployed for long enough periods of time to actually experience such discrimination. The more logical and policy relevant definition of true duration dependence is then to ask how the job-finding rate has changed for the representative group of unemployed workers at duration τ. We can write this conditional relative job finding probability as:

$$TDD^\tau(\tau) = \frac{\int_x f(x,0)u(x,\tau)dx}{\int_x f(x,0)u(x,0)dx} \tag{5.4}$$

which instead asks how the average job-finding rate changes *for the representative group of workers who are unemployed at duration* τ. This is the blue dashed line in Figure 6.

Figure 6: Counterfactual Duration Dependence in the Job Finding Rate

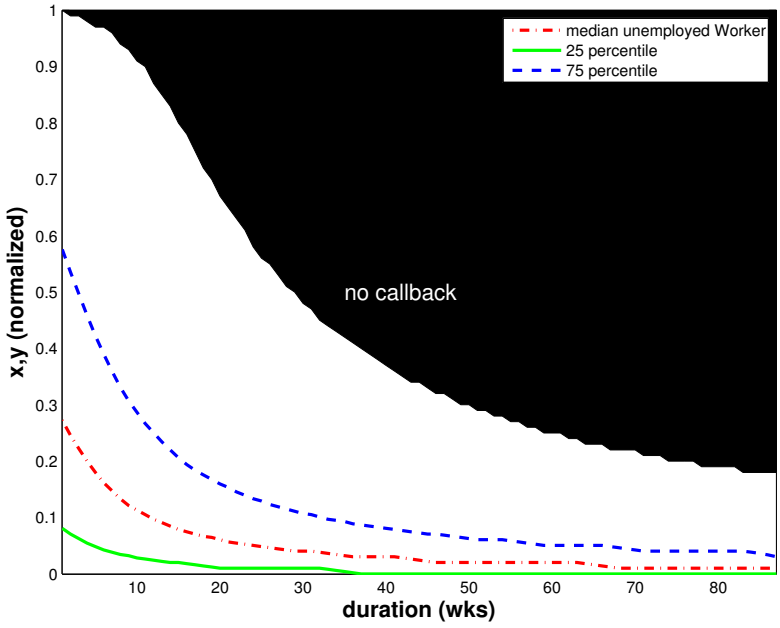


The 80% decline in the unconditional relative job-finding probability nearly disappears when we control for unobserved heterogeneity in this way, implying that the majority of the decline is a result of dynamic sorting. While there are still some workers who experience a decline in their job-finding rate (which is is why our definition could never be a flat line at 1), these workers exit quickly from unemployment.

The reason why the latter notion of true duration dependence is flat relates to the set of firms willing to hire low types and the set of firms that begin to discriminate - these two sets rarely intersect. If a firm were willing to hire low worker types, there would be no reason for him to ignore applications from the long-term unemployed. Figure 5 depicts the set of firms willing to hire duration τ workers in white, while the black shaded area represents firms that are not willing to hire duration τ workers. Since the distribution of available vacancies is independent of duration, the expanding black area implies that the callback rate is declining with unemployment duration.

Given the assumed production function, positive output pairs are pairs for which $x \geq y$. In Figure 7, we put both firm and worker types (normalized to be between 0 and 1) on the y axis, and unemployment duration on the x axis. It is clear from the picture that discrimination has consequences only for the type x workers that fall into the black area. These are the workers who could form viable matches with the firms that discriminate. We plot the 25th, median, and 75th percentile worker at every unemployment duration. The fact that even workers in the 75th percentile of the worker productivity distribution at duration τ are far below the rejection region explains why true duration dependence is minimal in Figure 6. The vast majority of the unemployed workers at duration τ would not form feasible matches with any of the firms that are discriminating against duration τ workers. This is precisely the reason for equilibrium discrimination and it means that for most workers, the set $I(\tau) \cap H(x)$ is not changing with unemployment duration, and their individual job-finding rates are almost flat with unemployment tenure.

Figure 7: The Incidence of Discrimination



5.1 Intuition: A Simplifying Example

Our preferred measure of true duration dependence is thus large whenever the set $I(\tau) \cap H(x)$ differs greatly from $I(0) \cap H(x)$. Put differently, a worker's job-finding probability will remain constant with duration as long as no firm that is relevant to her (i.e., in her hiring set) begins to discriminate. But because discrimination is statistical, for the majority of workers who are unemployed at longer durations, no relevant firms begin to discriminate.

To understand this result, we consider again the decision to interview a duration τ worker. Any firm y that discriminates against a duration τ worker by definition satisfies:

$$\int_{x^\star(y)} \frac{p(x,y) - b}{1 - \beta(1-\delta)} u(x|\tau) dx \leq \kappa(y)$$

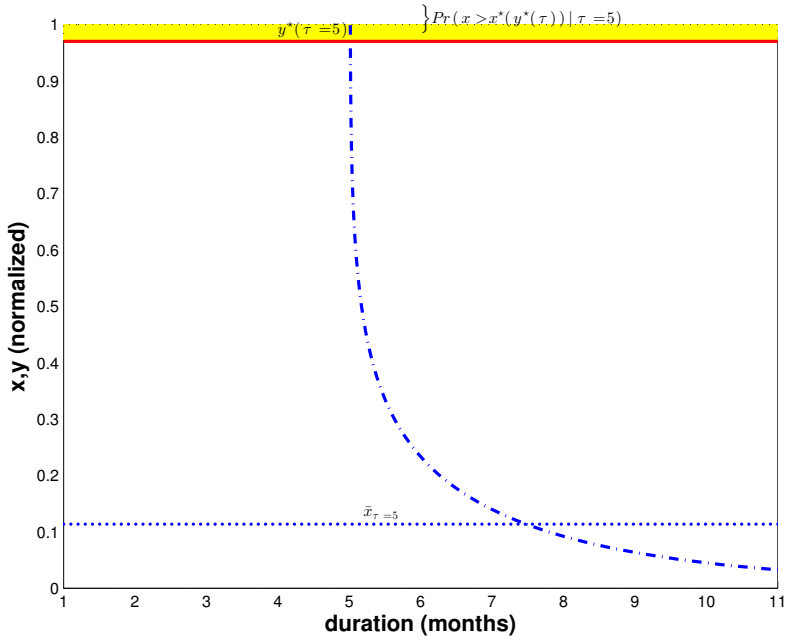
In particular, there is a threshold firm $\bar{y}(\tau)$ which satisfies the above with equality. Now, rearranging gives:

$$\frac{\kappa(\bar{y}(\tau))}{\mathbf{E}\left(\frac{p(x,\bar{y}(\tau))-b}{(1-\beta[1-\delta])} | x > x^\star(y), \tau\right)} = Pr(x > x^\star(\bar{y}(\tau))|\tau) \tag{5.5}$$

where the right hand side is just the probability of a firm y meeting someone that he would hire, and the left hand side is the size of the interview costs relative to the discounted present value of match surplus, conditional on positive surplus. To make analytical progress, assume that $b = 0$, and that $\kappa(y) = \tilde{\kappa} \cdot y$. With our production function, we have that a firm y hires every worker with $x > y$. Thus, the above simplifies to

$$\kappa(1 - \beta(1-\delta)) = Pr(x > \bar{y}(\tau)|\tau) \tag{5.6}$$

Figure 8: The Incidence of Discrimination



The term on the right hand side is exactly the probability that discrimination prevents a viable match from happening. The equation tells us that a share $1-\kappa(\beta(1-\delta))$ of all unemployed workers at duration τ does not experience discrimination by relevant firms y. As pointed out above, micro-evidence on hiring cost suggest a value of $\kappa = .75$ at a weekly frequency so we can set it to 1 here. Choosing β and δ accordingly we find that, conditional on a meeting, the probability that discrimination prevents a viable match from happening is less than .1%, independent of the amount of discrimination generated by the model. Relating this back to figure (7), it follows that 99.9% of the workers at any duration τ fall into the white area. While this specific result depends on several stark assumptions made in our example, it highlights the key aspects of the discrimination decision. Interview cost are meager compared to the discounted present value of a viable match.[12] Hence, in order for

[12] In a more general setting, the indifference condition implies that:

$$\frac{\kappa(\bar{(}\bar{y})(\tau))}{\frac{E(p(x,\bar{y}(\tau))-b}{[1-\beta(1-\delta)]}} = Pr(x > x^\star(\bar{y}(\tau))|\tau) \tag{5.7}$$

so that the probability a worker's type is larger than the cutoff worker type is bounded by the cost of an interview relative to the discounted present value of profits to the firm from the match.

a firm to toss out a worker's application purely based on duration, it must be very unlikely ex-ante for the worker-firm pair to match post interview.

6 The Cumulative Effects of Discrimination on Unemployment Levels

Theoretically, our above analysis has focused only on the share of workers within a single period who are wrongfully discriminated against. However, there may be some workers who remain unemployed for τ periods because they were discriminated against $\tau - 20$ periods ago, but not since then. Therefore, in this section we seek to measure the cumulative effect of discrimination on the level of unemployment. That is, how much unemployment can be explained by wrongful discrimination?

We can, in general, decompose the monthly probability of not finding a job into the following pieces:

$$1 - f(\theta, x, \tau) = (1 - \lambda_0) + \lambda_0 \left[\underbrace{\int_{y \in I(\tau)^C \cap H(x,\tau)} v(y)dy}_{discrimination} + \int_{y \in H(x,\tau)^C} v(y)dy \right]$$

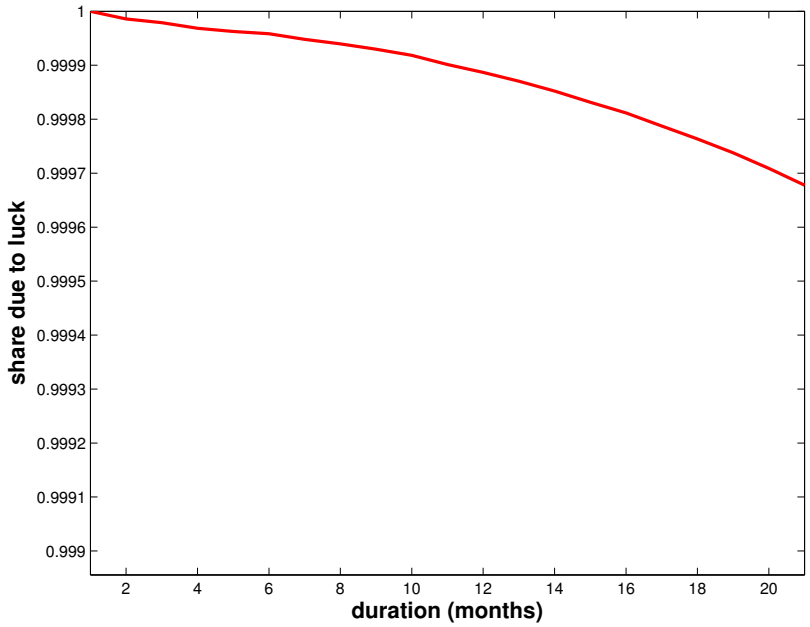
These, respectively, represent: the probability of not meeting a firm; the probability of meeting a firm who will not interview a worker, but ex post would have hired her; and the remaining ways of not finding a job.[13] In what follows, we think of the second group as workers who are unemployed due to discrimination.

Specifically, for the set of workers unemployed for τ periods, we denote the fraction that are unemployed due to discrimination as the fraction of workers who were ever rejected for interviews, but ex-post would have been hired within the last $\tau - 1$ periods. For example, if a

[13] These include the probability of meeting a firm that will not interview a worker, and would not have hired her ex post, and the probability of meeting with a firm who interviews a worker, but would not hire her ex post.

worker was turned down for an interview in period 2 by a firm that was in her hiring set, but subsequently never meets a firm due to bad luck, we include this worker in our calculations. The remaining workers are unemployed because of bad luck only. In Figure 9, we plot the evolution of this share with unemployment duration, unconditional on worker types.

Figure 9: The Cumulative Effects of Discrimination on Unemployment Levels



The logic for this result is largely the same as in the previous section. Since firms are rational, they have the correct beliefs about the distribution of the unemployment pool. That means they are also aware of how many workers are unemployed with duration τ who were discriminated against despite the fact that they are well-qualified. In every period, firms take this information into account so that the cumulative effects of a single instance of discrimination do not accumulate.

7 Conclusion

In this paper we develop an equilibrium search model with a two-stage hiring process that gives rise to employer screening and thus state dependence in callback rates and job-finding

rates. In response to facing unobserved worker heterogeneity and costly interviews, firms use the informational content of unemployment duration to screen workers at the interview stage. Despite the fact that the model features two-sided heterogeneity and asymmetric information, it is highly tractable and can be solved in closed form.

We show analytically that the likelihood that a firm dismisses a worker at the interview stage - even though that worker is qualified- is small. If discrimination is statistical (i.e. rather than taste-based a la Becker (1971) for example), then the very fact that a firm discriminates against the long-term unemployed reveals that it is unlikely to form a viable match with them. While it is certainly possible that firms have irrational beliefs, the behavior documented in Kroft et al. (2013) regarding variation in callbacks across labor markets suggests that firms are indeed rational, updating their beliefs as the distribution of workers in unemployment evolves.

Quantitatively, we use the estimated model to condition on unobserved heterogeneity to calculate the correct measure for state-dependence in job-finding probabilities resulting from state-dependence in callback rates documented in Kroft et al. (2013). We find that conditioning on unobserved heterogeneity nearly eliminates the decline in the job-finding rate with unemployment tenure. Our quantitative work confirms this. Even when we allow for an endogenous search intensity margin to amplify discrimination through discouragement, it is difficult to generate large effects of discrimination on the job-finding rate.[14]

This rather intuitive point is one that has been overlooked by the media and policy circles alike in interpreting the evidence regarding employer discrimination based on unemployment duration. In fact, it seems that this evidence prompted multiple states to ban firm discrimination altogether. We suspect that while the duration of unemployment may affect a worker's interview opportunities, it does not significantly affect the representative long-term unemployed worker's job market opportunities overall. Therefore, such firm behavior

[14]In an earlier version of the model we allowed for endogenous search intensity and the results featured the same qualitative features as we find now regarding true duration dependence. The results and further explanation can be found in the appendix.

is unlikely to be responsible for the large disparities between the job finding probabilities of the long-term and the short-term unemployed.

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Proofs

Proof of Proposition 1. Suppose that a firm is willing to hire a worker with $\hat{x} < x^\star(y)$. This must imply that $\frac{p(\hat{x},y)-b}{1-\beta(1-\delta)} \geq 0$. But $\frac{p(x^\star,y)-b}{1-\beta(1-\delta)} = 0$ and since p is weakly increasing, $p(\hat{x}, y) \geq p(x^\star, y)$ then $\frac{p(\hat{x},y)-b}{1-\beta(1-\delta)} \geq 0$. This can only hold if $\hat{x} = x^\star$.

Suppose $y \in H(x_1)$. Then $\frac{p(x_1,y)-b}{1-\beta(1-\delta)} \geq 0 \implies \frac{p(x_2,y)-b}{1-\beta(1-\delta)} \geq 0 \implies y \in H(x_2)$. Now, consider $x_1, x_2 \in \tilde{x}$ and the specific firm $y \in H(x_2)$ where $\frac{p(x_2,y)-b}{1-\beta(1-\delta)} = 0$. Since p is strictly increasing in $x \forall x \in \tilde{x}$, $y \notin H(x_1)$.

We want to show that $U(x|\tau)$ first order stochastically dominates $U(x|\tau+1)$:

$$\int_{\hat{x}}^{\bar{x}} u(x|\tau)dx \geq \int_{\hat{x}}^{\bar{x}} u(x|\tau)[1-f(x)]dx \;\; \forall \hat{x} \in X$$

or equivalently:

$$f(\bar{x}) \geq f(\hat{x}) \;\; \forall \hat{x} \in X$$

If firms are not discriminating, then the job-finding probability for a type x worker is given by:

$$f(x) = \int_{y \in H(x)} v(y)dy$$

Since $H(x_1) \subseteq H(x_2) \forall x_1, x_2 \in X$, $f(x_1) \leq f(x_2) \;\; \forall x_1, x_2 \in X$. Thus, since $U(x|\tau)$ FOSD $U(x|\tau+1)$, then expected surplus is strictly declining in duration. If firms discriminate, since the discrimination rule affects all worker's job-finding probabilities, the case is trivial.

Let $y^\star(\tau)$ be defined as:

$$\int_{x^\star(y^\star)} \frac{p(x, y^\star) - b}{1-\beta(1-\delta)} u(x|\tau)dx = \kappa$$

Since expected surplus is declining in duration for all firms y and interview costs are fixed,

$y^\star \in I(\tau)$, but $y^\star \notin I(\tau+1)$. Now, take all $y \in I(\tau+1)$. If $y \in I(\tau+1)$ then:

$$\int_{x^\star(y)} \frac{p(x,y)-b}{1-\beta(1-\delta)} u(x|\tau+1)dx \geq \kappa$$

Since expected surplus is higher at τ, if $y \in I(\tau+1)$ then $y \in I(\tau)$. Thus $I(\tau+1) \subset I(\tau)$. $\square$

Search Intensity

If workers could respond to discrimination, we might expect that it has more of a chance to affect the job-finding rate through discouragement. However, we show here that even allowing for search intensity does not break the general result. The reason relies on the same intuition as before. The choice of search intensity is a function of an individual's value of search. Since firms that discriminate would not hire the majority of workers they discriminate against, there is virtually no change in a worker's value of search, and thus there is minimal impact of discrimination on discouragement.

To introduce search intensity, we allow workers to provide search effort which directly affects their contact rate with firms. Specifically, instead of meeting firms at rate λ, workers choose their search intensity $s(\tau,x)$ and meet firms at rate $s(\tau,x)$. Searching is costly and the cost of search is convex with the following functional form:

$$c(s(\tau,x)) = \frac{\gamma_0}{1+\gamma_1} s^{1+\gamma_1}$$

Finally, we assume that workers get a share $\alpha > 0$ of the surplus to provide them with an incentive to search.

The choice of search effort implies that the value of unemployment is no longer constant in duration. Since a worker's job-finding probability is a function of duration, her search effort and thus current utility will also be a function of duration. The value functions thus

become:

$$U(x,\tau) = \max_{s(x,\tau)} b - c[s(x,\tau)] + \beta s(x,\tau) \int_{I(\tau)\cap H(x)} W(x,y,\tau+1)v(y)dy + \beta \left(1 - s(x,\tau) \int_{I(\tau)\cap H(x)} v(y)dy\right) U(x,\tau+1)$$

$$W(x,y,\tau) = w(x,y,\tau) + \beta \left\{(1-\delta)W(x,y,\tau) + \delta U(x,0)\right\}$$

$$J(x,y,\tau) = p(x,y) - w(x,y,\tau) + \beta(1-\delta)J(x,y,\tau)$$

Combining these, we can specify the surplus function as well as the optimal search intensity:

$$S(x,y,\tau) = p(x,y) - b + c[s(x,\tau)] + \beta(1-\delta)S(x,y,\tau) - \beta s(x,\tau) \int_{I(\tau)\cap H(x,\tau)} \alpha S(x,y,\tau+1)v(y)dy + \beta\delta\left[U(x,0) - U(x,\tau+1)\right]$$

$$c'[s^\star(x,\tau)] = \beta \int_{I(\tau)\cap H(x,\tau)} \alpha S(x,y,\tau+1)v(y)dy$$

The firm's duration cutoff rules will be defined implicitly by:

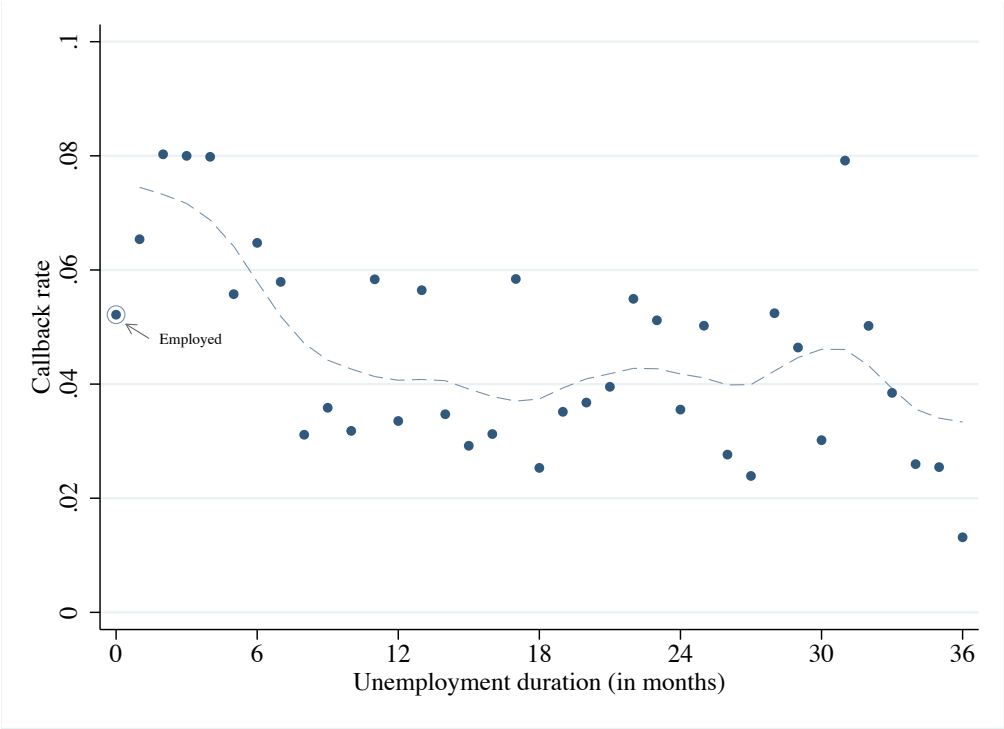
$$\int_X \max\{(1-\alpha)S(x,y,\tau^\star(y)),0\}u(x|\tau^\star(y))dx = \kappa$$

We re-run the model assuming $\gamma_0 = 1$. We similarly find that discrimination has no effect on duration dependence in the job-finding rate. Intuitively, this is again because the optimal choice of search intensity is a function of the intersection of the two sets $I(\tau) \cap H(x,\tau)$. The only workers who will adjust their search intensity are the workers who experience

discrimination at the interview stage who otherwise would have been hired.

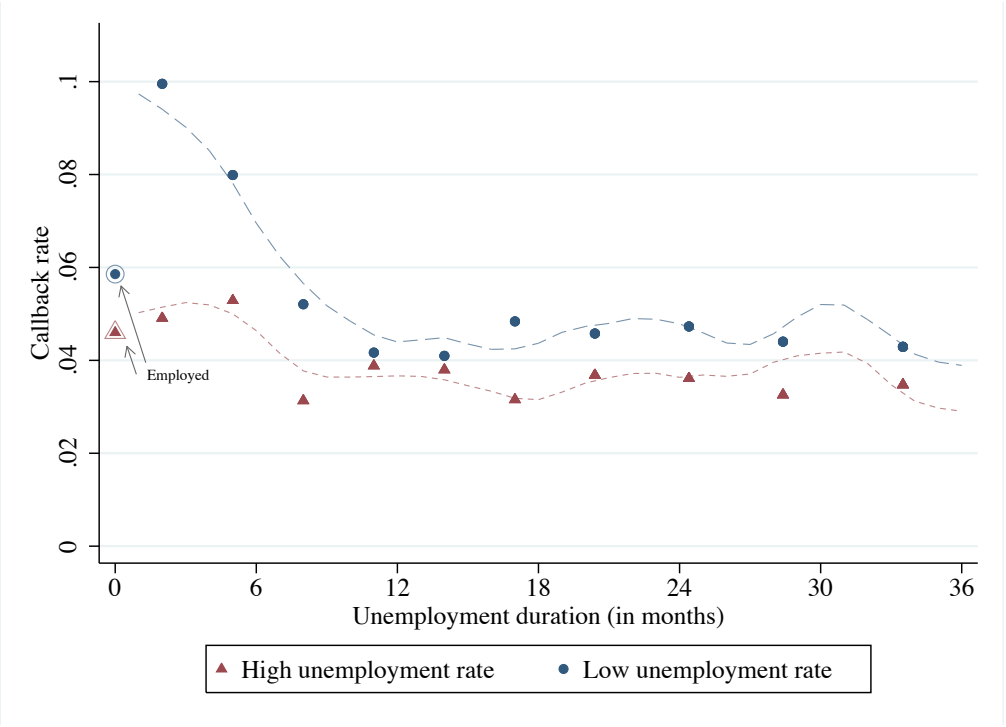
Tables and Figures

Figure 10: Empirical Callback Rates by Unemployment Duration



Source: Kroft, Lange, and Notowidigdo (2013)

Figure 11: Empirical Callback Rates by Unemployment Duration



Source: Kroft, Lange, and Notowidigdo (2013)