Search and Matching by Race and Gender

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- **Black-white differences:**
  - *Pre-labor market factors*, such as education and skill development largely explain wage gap (O'Neill 1970, O'Neill 1990, Neal and Johnson 1996, Carneiro, Heckman, and Masterov 2005).
  - *Occupational choices* widen gap (Golan, James and Sanders, 2021).
  - Probability a prospective employer follows up on a *job application* is affected by candidate's race (Bertrand and Mullainathan, 2004).
- **Gender differences (surveyed in Blau and Kahn, 2017):**
  - *Workforce participation and hours worked* play a large role.
  - *Statistical discrimination* driven by firm specific investment explain some (Gayle and Golan 2012, Xiao 2021).
  - *Occupation and industry* choices play a role.
  - *Negotiation strategies* differ by gender (Babcock and Laschever, 2007).
  - *Not uniformly distributed across occupations*: female CEOs are paid as well and promoted as quickly as males (Gayle, Golan, and Miller, 2012).

- **The right to free association ameliorates** economic effects of *taste-based personal discrimination*:
  - if there are *constant returns to scale*.
  - or more generally if optimal plant size is "small" (Becker 1956).
  - and is revealed through *equilibrium sorting*.
- Therefore discrimination aginst *minorities* might be more pronounced:
  - in organizations that are hard to *replicate on a smaller scale*.
  - where *firm specific capital* might induce *lifetime employment*.
- Furthermore in competitive equilibrium, discrimination could be:
  - treated the same way treated as a(nother) nonpecuniary amenity.
  - factored into compensating differentials.
- **Exhaustively processing every applicant** for a position is costly.
- Costs can be reduced by winnowing the applicant pool in stages, but:
  - this is an inefficient way to process information.
  - is counterproductive if different goals are pursued at different stages.

Introduction

Aim of paper (and work in progress)

- **Describe empirical regularities in job search and matching**:
  - with *unique data* set taken from a large firm showing . . .
    search activities by employees.
    hiring procedure that culls applicants in stages.
    job spell durations and *promotions.*
- **Develop and estimate a principal agent model**:
  - with a *multistage choice process* that endogenizes consideration sets.
  - to rationalize an apparent *lack of teamwork* within the firm.
  - embedded in a *rational expectations equilibrium* with two sided search.
- **Use the estimated model** to:
  - *decompose hiring costs* between agency and multistage choice.
  - conduct counterfactuals by *perturbing personal taste* parameters.
  - predict effects of *imposing regulations* on hiring.

Data

Description

- Dataset provided by a *large anonymous firm* on:
  - a 5 year period in the first decade of the 21st century.
  - all its job vacancies, employees, job applicants, and hiring details.
- For each *job vacancy* we have:
  - a brief job description including its division and salary range.
- For each *job application* we observe whether candidate:
  - met minimal qualifications.
  - voluntarily withdrew application.
  - was interviewed.
  - was offered the job.
- For each *employee* we observe:
  - demographic information (race, gender, age, education).
  - all job applications and outcomes in this 5 year time period.
  - supplemented by annual wage data from firm for up to 20 years.

Data

Descriptive statistics – demographics of candidates

We compare the demographics of our sample to the ACS, looking only at labor market participants located in the Midwest.

	Sample	ACS		Sample	ACS
Age under 18	0.0020	0.024	High school or less	0.22	0.48
Age 18-29	0.31	0.21	Some college	0.38	0.25
Age 30-39	0.26	0.19	College degree	0.32	0.18
Age 40-49	0.24	0.25	Graduate degree	0.091	0.09
Age 50-59	0.17	0.23	African American	0.045	0.058
Age 60-69	0.023	0.084	Female	0.54	0.48
Age above 70	0.0013	0.022			
Num obs	62,405	344,632			

Data

Descriptive statistics on applications

Applications per candidate	4.04 (8.69)
Applications per job	49.19 (76.92)
Qualified and interested applications per job	20.3 (35.9)
Interviewed candidates per job	7.38 (12.81)
Applications with no experience	0.91
Number of applications	252,256
Number of vacancies	5,365

Standard errors in parentheses.

Data

Number of applications by race and gender

	All	Qualified and interested
	(1)	(2)
African American	0.701***	0.341***
	(0.0715)	(0.0465)
Female	0.108***	0.0922***
	(0.0306)	(0.0199)
Duration working for firm	0.140***	0.131***
	(0.0254)	(0.0165)
Observations	87394	87394

Standard errors in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. The dependent variable is the number of applications submitted. Controls for year, education, and age included but not reported. We additionally control for the square of the duration working for the firm.

Data

Regressing average salary of job posting on race and gender (and other variables)

	All		Qualified and interested	
	(1)	(2)	(3)	(4)
African American	-1120.5***	-266.7	-1329.5***	-971.1**
	(65.06)	(393.6)	(76.37)	(461.9)
Female	-523.2***	-1888.2***	-600.6***	-2094.9***
	(34.80)	(174.0)	(39.87)	(197.3)
Previous year salary		0.180***		0.191***
		(0.00480)		(0.00541)
Observations	227198	10549	158326	8071

Standard errors in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. The job posting reports the minimum and maximum salaries. The dependent variable is the average of those 2 values. We additionally control for the number of applications, experience working for the firm, location of the position, age, and education. We also include division and occupation fixed effects.

Data

Race and gender coefficients obtained from probits estimating survival probabilities

	African American	Female
Outcome variable: Not qualified or not interested		
Not qualified	0.0372***(0.00238)	-0.000659 (0.00132)
Not interested	0.0143***(0.00269)	0.00874***(0.00149)
Outcome variable: Interviewed		
All qualified and interested candidates	-0.0328***(0.00500)	-0.00318 (0.00249)
With prior experience	-0.0524*** (0.0199)	-0.00513 (0.00940)
New applicants	-0.0301***(0.00488)	-0.00361 (0.00245)
Outcome variable: Job offer		
All interviewed candidates	0.0244**(0.00979)	0.00877 (0.00448)
With prior experience	0.0562**(0.0273)	0.0227 (0.0120)
New applicants	0.0199*(0.0104)	0.00560 (0.00479)

We report marginal effects from a probit regression. We also include controls (not reported) for experience at the firm and division, salary of the job posting, location, education, age, number of applications, and year, division, and occupation fixed effects.

Data

Duration of job(s) within a division

	OLS	Tobit
African American	-0.919***	-1.176***
	(0.215)	(0.288)
Female	-0.304***	-0.761***
	(0.101)	(0.135)
Year job started		0.809***
		(0.00995)
Observations	11342	11342

We additionally control for education, unemployment and labor market participation in a given year, and include division and occupation fixed effects.

- The Tobit is motivated by sample censoring:

$$duration = \begin{cases} demographics \cdot coefficients + error & \text{if } duration \leq D \\ D & \text{if } duration > D \end{cases}$$

Data

Wage regression

	All	Job switchers
African American	-0.101 ***	-0.0632
Female	-0.0938 ***	-0.0920 ***
Duration in current division	0.0957 ***	0.0540 ***
Experience squared	-0.00337 ***	-0.00184 ***
Switches divisions	0.142 ***	0.0678
Number applications for job		-0.000300 ***
Salary of job posting		0.0000203 ***
Constant	9.776 ***	9.125 ***
Observations	50519	1210

We additionally control for age and education, and include year and division fixed effects. We include occupation fixed effects in column (2).

Data

Summarizing the differences compared to white males

	Black	Female
make lower entry level salaries	$\surd$	?
apply for more jobs	$\surd$	$\surd$
apply for lower salary jobs	$\surd$	$\surd$
are more likely to withdraw their application	$\surd$	$\surd$
are less likely to meet minimal qualifications	$\surd$	
are less likely to be interviewed	$\surd$	
are more likely to receive job offer	$\surd$	
earn less, given the salary posted for the job		$\surd$
have shorter job spells	$\surd$	$\surd$

Motivation for Model

A matching problem

- The *firm* uses a *multistage* selection procedure to . . .
  1. build a choice set (create an applicant pool).
  2. make a choice from the set (hire an applicant from the pool).
- The *worker* . . .
  1. shops for a durable good (searches for job opportunities).
  2. discards less valuable options (withdraws some applications).
  3. periodically replaces the good (quits existing job).
- The *matching mechanism* is embedded . . .
  - within a *competitive equilibrium*.
  - where there are *rational expectations*.

Motivation for Model

Multistage choice

- **Multistage choice**:
  - *partially rank orders* candidates by *exclusion/inclusion* criteria.
  - limits final *consideration set* to candidates satisfying the criteria .
- **Rank ordering a subset** of a candidate's characteristics:
  - *discards information* about the joint distribution.
  - may be optimal if preferences have *lexicographic* features.
- If the decision-making cost does not increase with the choice set:
  - multistaging choices typically reduces the value of the choice set.
  - the firm would *consolidate* all vetting into one stage.
- The **rationale for multiple stages** derives from:
  - the *benefits of selection* over a random choice.
  - the positive marginal cost of processing *additional candidates*.
- To **optimally sequence** multiple stages, schedule:
  - more costly stages later.
  - more valuable stages earlier.

Motivation for Model

An additional complication in multistage choice

- **Initial screen . . .**
  1. reviews answers to *close-ended questions* in applications.
  2. are *cheap* to administer but *limited* in scope.

  low cost and objective $\Longrightarrow$ *firm interests predominate*

- **Committee selects (interviewee) consideration set . . .**
  1. reviews answers to *open-ended* questions in applications.
  2. conducts background checks at its *discretion*.

  costly and hard to monitor $\Longrightarrow$ *committee interests predominate*

- **Interviews . . .**
  1. are *time intensive* but flexible enough to be perfunctory or comprehensive.
  2. may give *candidate opportunity* to present her case for appointment.
  3. can be *reviewed* retrospectively (with transcripts or recordings).

  very costly but easy to monitor $\Longrightarrow$ *firm interests predominate*

Motivation for Model

A principal agent problem

- The committee shrinks the set of candidates, but:
  - the preferences of the committee and the firm may not coincide.
  - the committee might include future colleagues of the new hire.
  - committee is unlikely to pursue goals like firm value maximization.
- If the committee also interviews, differential monitoring induces different objectives being pursued at different stages.
- If the committee does not value information obtained at interviews:
  - the committee submits only one candidate for interview.
  - the preferences of the committee and the firm cannot be distinguished from each other.
- When more than one candidate is interviewed:
  - new information valued by the committee is gathered in the final stage.
  - committee and firm preferences do not diverge too much (partly because the firm typically appoints the committee).

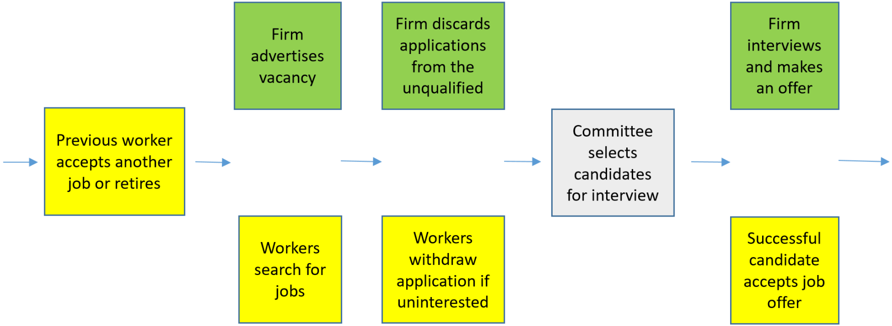
Model

Time line for hiring and spell length

1. A *firm* advertises a *vacancy*, internally and externally.
2. Workers are more likely to see the advertisement:
   - if they *search* more exhaustively
   - but search is a costly activity.
3. Some applications are withdrawn from consideration because:
   - candidates discover they *prefer their current employment* status.
   - the candidate is *not minimally qualified* for the advertised position.
4. A *committee* shrinks this pool of *viable candidates* to a *consideration set* of interviews.
5. The firm *hires* a worker from the consideration set to fill the vacancy.
6. Worker *quits* for another job (endogenous) or *retires* (exogenous).

Motivation for Model

Flow chart



Model

Advertising a vacancy and the first cull

- Generating the pool of applicants:
  - s denotes *job search intensity* of potential applicants.
- $N \in \{1, 2, \ldots\}$ denotes the number of applications received:
  - drawn from a probability distribution $F_N(s)$
  - $E[N|s] \equiv \sum_{N=0}^{\infty} NF_N(s)$ is increasing in s.
- At the first cut:
  - firm culls *unqualified* applicants by setting $d_n^{(q)} = 0$ if $n \in \{1, 2, \ldots N\}$.
  - if *uninterested*, applicant n can withdraw by setting $d_n^{(i)} = 0$.
- Defining $d_n^{(v)} \equiv d_n^{(q)} d_n^{(i)}$ this yields:

$$N^{(v)} \equiv \sum_{n=1}^{N} d_n^{(v)} < N$$

viable candidates, a set denoted by $d^{(v)} = \left(d_1^{(v)}, \ldots, d_N^{(v)}\right)$.

Model

Selecting the consideration set and hiring a candidate

- **The committee scores viable candidates for interviewing**:
  - $d_n^{(c)} \in \{0,1\}$, where $d_n^{(c)} = 1$ means interviewing n.
  - $d_n^{(c)} \leq d_n^{(v)}$ because *only viable candidates* are interviewed.
  - $N^{(c)} \equiv \sum_{n=1}^{N} d_n^{(c)}$ candidates are interviewed.
  - $d^{(c)} \equiv \left(d_1^{(c)}, \ldots, d_N^{(c)}\right)$ defines the *consideration set*.
- **Finally the firm makes an offer**:
  - $d_n \in \{0,1\}$ where $d_n = 1$ means n receives the job offer.
  - $d_n \leq d_n^{(c)}$ because successful candidates have been interviewed.
  - $\sum_{n=1}^{N} d_n = 1$ since only one offer is made.
  - $d \equiv (d_1, \ldots, d_N)$ defines the *offer set*.

Model

Firm conducts interviews and makes an offer

- Each position is a stationary renewal problem:
  - of replacing a worker who quits.
  - linked only through equilibrium conditions characterizing job search.
- Upon offering n the job at time $t = 0$:
  - the firm pays individual specific initial orientation cost ϵ_n.
  - ϵ_n is *iid* with distribution function $G(\cdot)$.
- $x_{nt} \in \mathbb{X}$ describes characteristics of n at $t \in \{0, 1, \ldots\}$:
  - and evolves with transition probability $H(x_{n,t+1} | x_{nt})$.
- At $t_n \in \{0, 1, \ldots\}$, a random time, n quits:
  - for another position (depending stochastically on her search intensity).
  - to retire (exogenous in this model).
- The firm nets an expected value of:
  - $\omega(x_{n0}) = E\left[\sum_{t=1}^{t_n} \delta^t \left[h(x_{nt}) - w(x_{nt})\right] | x_{n0}\right]$
  - from paying n wages of $w(x_{nt})$ each period t to produce $h(x_{nt})$.
  - discounting benefits and costs at rate δ per period.

Model

Firm conducts interviews and makes an optimal offer

- Denote by v_0 the exante expected value of the firm.
- At the final stage the firm chooses $d \equiv (d_1, \ldots, d_N)$ to maximize:

$$\sum_{n=1}^{N} d_n \left[\omega\left(x_{n0}\right) + E\left[\delta^{t_n} \left| x_{n0}\right.\right] v_0 + \epsilon_n\right] \tag{1}$$

- Suppose $\widehat{d} = \left(\widehat{d}_1, \ldots, \widehat{d}_N\right)$ solves (1) and:
  - committee observes $x^{(c)} \equiv \left(x_1^{(c)}, \ldots x_N^{(c)}\right)$ where $x_n^{(c)} \in \mathbb{X}^{(c)} \subseteq \mathbb{X}$.
  - $p\left(d^{(c)}, x^{(c)}\right) \equiv E\left[\widehat{d}_n \left| d^{(c)}, x^{(c)}\right.\right]$ denotes the expected CCPs.
  - λ denotes the cost of interviewing a candidate.
- Given $\left(d^{(c)}, x^{(c)}\right)$ the *expected social surplus* is:

$$v\left(d^{(c)}, x^{(c)}\right) \equiv E\left\{\sum_{n=1}^{N} \widehat{d}_n \left[\omega\left(x_{n0}\right) + E\left[\delta^{t_n} \left| x_{n0}\right.\right] v_0 + \epsilon_n\right] \left| x^{(c)}\right.\right\}$$

$$\Longrightarrow v_0 = \sum_{N=1}^{\infty} F_N(s) E\left[v\left(\widehat{d}^{(c)}, x^{(c)}\right) - \lambda \sum_{n=1}^{N} \widehat{d}_n^{(c)}\right] \tag{2}$$

Model

Hiring committee selects consideration set (of applicants for firm to interview)

- Expected utility of committee from hiring candidate n is:

$$u\left(x_n^{(c)}\right)+\epsilon_n^{(c)}+\gamma E\left\{\sum_{t=1}^{t_n}\delta^t\left[h\left(x_{nt}\right)-w\left(x_{nt}\right)\right]+\delta^{t_n}v_0+\epsilon_n\left|x^{(c)}\right.\right\}$$

where:

- $\epsilon^{(c)}\equiv\left(\epsilon_n^{(c)},\ldots,\epsilon_N^{(c)}\right)$ where $\epsilon_n^{(c)}$ is *iid*.
- $u\left(x_n^{(c)}\right)+\epsilon_n^{(c)}$ measures divergence of committee preferences.

- The committee's optimal consideration set $\widehat{d}^{(c)}$ maximizes:

$$\sum_{n=1}^{N}d_n^{(c)}E\left\{p\left(d^{(c)},x^{(c)}\right)\left[u\left(x_n^{(c)}\right)+\epsilon_n^{(c)}\right]\right\}+\gamma v\left(d^{(c)},x^{(c)}\right)\qquad(3)$$

Model

Workers problem

- *Description of worker's problem*:
  - derives pecuniary and nonpecuniary flow benefits from current job.
  - chooses job search intensity (flow rate of new job opportunities).
  - can decline new opportunities, and/or adjust search intensity.
- *Notation for state transitions and choices*:
  - x_τ her state variables at τ.
  - $y_\tau^{(o)} \in \{0,1\}$ whether new job opportunity arrives at τ or not.
  - s_τ her search intensity at τ $\begin{cases} \text{choice variable if } y_\tau^{(o)} = 1 \\ \text{but } s_\tau = s_{\tau-1} \text{ if } y_\tau^{(o)} = 0 \end{cases}$
  - j her current job.
  - $G_j(s,x)$ probability that $y_\tau^{(o)} = 1$ conditional on (j,s,x)..
  - $y_\tau \in \{0,1\}$ whether she applies for new job when $y_\tau^{(o)} = 1$.
- (s,y) *specifies* (s_τ, y_τ) *when* $y_\tau^{(o)} = 1$, *and depends on*:
  - her human capital x_τ and characteristics of her current job j.
  - characteristics of her new job opportunity $j+1$.

Model

Worker's utility

- The worker chooses (s, y) to maximize:

$$\sum_{j=1}^{\infty} E_{s,y} \left\{ \delta^{\tau_j} \epsilon_j + \sum_{\tau=\tau_j}^{\tau_{j+1}} \left[w_j \left(x_\tau \right) + b_j \left(x_\tau \right) - s_\tau \right] \right\} \tag{4}$$

where:

- $j \in \{1, 2, \ldots\}$ indexes jobs (and job spells).
- $\tau \in \{0, 1, \ldots\}$ is her age,
- τ_j is her age when beginning her j^{th} job.
- ϵ_j *iid* nonpecuniary turnover benefit or cost moving to j.
- $w_j \left(x_\tau \right)$ wage earnings in position j with state variables x_τ.
- $b_j \left(x_\tau \right)$ are nonpecuniary (flow) benefits.
- s_τ denotes her search intensity at τ.

Model

Recursive representation of worker's problem

- Denote expected value of lifetime earnings by:
  - $V_j(x_\tau)$ if $y_\tau^{(o)} = 1$ (new job opportunity arrives).
  - $\widetilde{V}_j(x_\tau)$ if $y_\tau^{(o)} = 0$ (no choices) where:

$$\widetilde{V}_j(x_\tau) \equiv w_j(x_\tau) + b_j(x_\tau) - s_{\tau-1} + \delta\Big[G(s, x_{\tau+1})V_j(x_{\tau+1}) + [1 - G(s, x_{\tau+1})]\widetilde{V}_j(x_{\tau+1})\Big]$$

  - $\underline{V}_j(x_\tau)$ if $y_\tau^{(o)} = 1$ but $y_\tau = 0$ (the worker declines new opportunity), where:

$$\underline{V}_j(x_\tau) \equiv \max_s \left\{ \begin{array}{l} w_j(x_\tau) + b_j(x_\tau) - s \\ +\delta\Big[G(s, x_{\tau+1})V_j(x_{\tau+1}) + [1 - G(s, x_{\tau+1})]\widetilde{V}_j(x_{\tau+1})\Big] \end{array} \right\}$$

  - $\overline{V}_j(x_\tau)$ if worker is hired, where:

$$\overline{V}_j(x_\tau) \equiv \max_s \left\{ \begin{array}{l} [w_{j+1}(x_\tau) + b_{j+1}(x_\tau) - s + \varepsilon_{j+1}] \\ +\beta\left[\begin{array}{l} G(s, x_{\tau+1})V_{j+1}(x_{\tau+1}) \\ +[1 - G(s, x_{\tau+1})]\widetilde{V}_{j+1}(x_{\tau+1}) \end{array} \right] \end{array} \right\}$$

- An optimal rule is to set $y_\tau = 1$ if and only if $\overline{V}_j(x_\tau) > \underline{V}_j(x_\tau)$.
- Let $\Psi_{j+1}(x_\tau)$ denote the (endogenously determined) probability that an application for the new job opportunity is successful conditional on applying. Then:

$$V_j(x_\tau) = \mathbf{1}\left\{\overline{V}_j(x_\tau) > \underline{V}_j(x_\tau)\right\}\Psi_{j+1}(x_\tau)\overline{V}_j(x_\tau) + \left[1 - \mathbf{1}\left\{\overline{V}_j(x_\tau) > \underline{V}_j(x_\tau)\right\}\Psi_{j+1}(x_\tau)\right]\underline{V}_j(x_\tau)$$

- A **stationary rational expectations equilibrium** is defined by:

$$\left(\widehat{w}, \widehat{d}, \widehat{s}, \widehat{y}, \widehat{d}^{(c)}\right)$$

satisfying the following properties:

1. (*individual optimization*) As a best response to $\widehat{w}$ and the strategies of the other players:
   - $\widehat{d}$ solves the firm's problem (1) and (2)
   - $\widehat{d}^{(c)}$ solves the committee's problem (3)
   - $(\widehat{s}, \widehat{y})$ solves the worker's problem
2. (*market clearance*) a free entry condition plus efficient turnover sets $v_0 = 0$, and $w(x_{nt}) = h(x_{nt})$ for $t \geq 1$.
3. (*rational expectations*) the probability distributions defining the laws of motion coincide with subjective beliefs the player types hold.

1. **Labor demand**
   - *(hiring d)* Given the firm's value function v_0 and starting wage $w(x_{n0})$, (1) simplifies to a static discrete choice optimization problem.
   - *(consideration set $d^{(c)}$)* The solution to (1) feeds directly into the committee's problem characterized by (3).
2. **Labor supply**
   - (*search intensity s and withdrawals y*) Solve for (s, y) in the worker's problem using a recursion that satisfies conditions for the contraction mapping to apply.
3. **Market clearance**
   - A free entry condition would set $v_0 = 0$, implying all firm surplus is transferred to labor.
   - Since utility is linear wages are only determined up to their expectation.

Identification and Estimation

Parameterizing the model

- *Wage equation* $w(x_{nt}) = x_{nt}\beta^{(w)} + \epsilon_{nt}$
  - $x_{nt} \in \mathbb{X}$ observed and ϵ_{nt} unobserved *iid* measurement error
  - $\mathbb{X}$ includes age, education, race, gender, tenure, lagged compensation.
- Firm's *production function net* of wages:
  - $\omega(x_{nt}) \equiv h(x_{nt}) - w(x_{nt}) = x_{nt}\beta$
  - ϵ_n is *iid* T1EV unobserved
- *Divergence* of committee preferences from the firm's:
  - $u\left(x_n^{(c)}\right) = x_n^{(c)}\alpha$ where $x_n^{(c)} \equiv x_{n0} \in \mathbb{X}$
  - $\epsilon_n^{(c)}$ is *iid* standard normal unobserved
- Probability of *new job opportunity* for worker:
  - $G(s_\tau, x_\tau)$ is a logit/probit
  - s choice variable measured by hazard rate to new job opportunity
  - $F_N(s)$, *cdf* for *number of applications*, formed from $G(s_\tau, x_\tau)$
- Transition of *worker's state variables*:
  - $H\left(x_{x_{\tau+1}} | x_\tau\right)$ is degenerate (deterministic)

Stepwise Estimation

Firm preferences (logit)

- Denote by $\left(\widetilde{\beta}, \widetilde{\delta}, \widetilde{v}_0\right)$ the logit estimates obtained from:

$$v\left(d^{(c)}, x, \epsilon\right) \equiv \max_{d \left| d^{(c)} \right.} \sum_{n=1}^{N} d_n \left\{ x_{n0}\beta + E\left[\delta^{t_n} \left| x_{n0} \right.\right] v_0 + \epsilon_n \right\}$$

- Form estimates of:

$$\widetilde{p}_n\left(d^{(c)}, x\right) = \frac{\widehat{d}_n^{(c)} \exp\left\{ x_{n0}\widetilde{\beta} + E\left[\widetilde{\delta}^{t_n} \left| x_{n0} \right.\right] \widetilde{v}_0 \right\}}{\sum_{m=1}^{N} \widehat{d}_m^{(c)} \exp\left\{ x_{m0}\widetilde{\beta} + E\left[\widetilde{\delta}^{t_m} \left| x_{m0} \right.\right] \widetilde{v}_0 \right\}}$$

$$\widetilde{v}^{(c)}\left(d^{(c)}, x\right) = \ln\left\{ \sum_{n=1}^{N} d_n^{(c)} e^{x_{n0}\widetilde{\beta} + E\left[\widetilde{\delta}^{t_n} \left| x_{n0} \right.\right] \widetilde{v}_0} \right\} + 0.57\ldots$$

Stepwise Estimation

Committee preferences (simulated methods of moments)

- Temporarily suppose:
  - $\left(\widetilde{\beta}, \widetilde{\delta}, \widetilde{v}_0\right)$ denotes firm preferences
  - $\left(\alpha, \gamma, \lambda^{(c)}, \epsilon_n^{(c)}\right)$ denotes committee preferences
- The committee's optimal consideration set $\widetilde{d}^{(c)}\left(x; \alpha, \gamma, \lambda^{(c)}, \epsilon_n^{(c)}\right)$ comes from choosing $d^{(c)}$ to maximize:

$$\sum_{n=1}^{N} d_n^{(c)} \left\{ \widetilde{p}_n \left(d^{(c)}, x\right) \left[x_{n0}\alpha + \epsilon_n^{(c)} + \widetilde{v}^{(c)} \left(d^{(c)}, x\right)\right] - \lambda^{(c)} \right\}$$

- Estimates of $\left(\alpha, \gamma, \lambda^{(c)}, \epsilon_n^{(c)}\right)$ are based on:
  - assuming a parametric functional form for $\epsilon_n^{(c)}$ (say T1EV)
  - orthogonality conditions implied by:

$$E\left[d^{(c)} - \widetilde{d}^{(c)}\left(x; \alpha, \gamma, \lambda^{(c)}, \epsilon_n^{(c)}\right) |x\right] = 0 \tag{5}$$

Stepwise Estimation

Simulated methods of moments

- To estimate $\left(\alpha, \gamma, \lambda^{(c)}\right)$:
  1. Simulate draws for $\epsilon_n^{(c)}$ for each application.
  2. Form instruments from x.
  3. Minimize a quadratic with respect to $\left(\alpha, \gamma, \lambda^{(c)}\right)$ based on orthogonality conditions implied by (5) using the instruments.
- The computational challenge to implementing this estimator arises from the number of consideration sets:
  - To simplify computation, assume at most 7 candidates are interviewed.
  - This leaves 486,949,266 **million** possible consideration sets!
  - For example if there are 20 qualified and interested candidates for one position, the number of consideration sets is:

$$\sum_{size=1}^{7} \frac{20!}{size!\,(20-size)!} = (20 + 190 + \ldots + 77,520) = 137,979$$

Stepwise Estimation

Feasible consideration sets defined

- We developed an algorithm to eliminate infeasible interview sets.
- Categorize each application by one of 32 *types*:
  - race (black or non black)
  - gender
  - education (high school, some college, college, or graduate education)
  - experience at the firm (internal or external applicant).
- Also partition vacancies into one of a finite number of *positions*:
  - Not all types apply to every position.
  - Applicant types never applying to a given position are called *infeasible*.
- Suppose candidates m and n, who have the same type:
  - apply (and are qualified) for the same job
  - and $\epsilon_m^{(c)} > \epsilon_n^{(c)}$.
  - If n but not m is interviewed, the consideration set is infeasible
- *Feasible* consideration sets are the complement of the infeasible ones.

Stepwise Estimation

Infeasible consideration sets are ignored

- The optimal consideration set is feasible.
- In our sample there are:
  - 9 million feasible consideration sets
  - 486,949,256 million infeasible consideration sets
- One job in our data has 20 qualified and interested applicants, consisting of only 5 types:
  - 2 are type A (some college, male, white, no experience)
  - 7 are type B (college, male, white, no experience)
  - 1 is type C (college, female, white, no experience)
  - 5 are type D (graduate education, male, white, no experience)
  - 5 are type E (graduate education, female, white, no experience)
- In this example there are:
  - 422 feasible consideration sets.
  - 137,557 infeasible consideration sets.

Estimation

Parameter estimates

	Interview	Hire
High school	-1.12	3.84
Some college	-0.17	1.98
College	0.056	1.06
Female	-1.10	-1.28
African American	-1.22	-2.82
Experience in department	-1.52	0.36
Parameter on firm surplus	8.65	
Standard deviation of shocks	2.20	
Cost of interview	1.86	
Continuation value of firm		47.50