

Interviews and Adverse Selection*

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Abstract

Interviewing in professional labor markets is a costly process for firms. Moreover, poor screening can have a persistent negative impact on firms' bottom lines and candidates' careers. In a simple dynamic model where firms can pay a cost to interview applicants who have private information about their own ability, potentially large inefficiencies arise from information-based unemployment, where able workers are rejected by firms because of their lack of offers in previous interviews. This effect may make the market less efficient than random matching. We show that the first best can be achieved using either a mechanism with transfers or one without transfers.

Keywords: Decentralized Labor Markets, Professional Labor Markets, Asymmetric Information, Interview costs, Matching

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1 Introduction

The process of screening professional workers through interviews is costly for firms. Banks, consulting firms, and manufacturing firms dedicated between 7%-9% of the total compensation (base salaries) of first year hires to recruiting staff salaries in 2006.¹ The time cost of recruiting is also large - in 2006, it took between 41 and 99 days to fill executive jobs at these firms.² Furthermore, when firms outsource the recruiting to headhunters, they pay up to one third of the new hire's first year base salary.³

The interview process can be very costly for workers as well. Despite firms' attempts at screening, asymmetric information may persist⁴, and the poor placement of a good candidate may seriously impact the candidate's career prospects. Oreopoulos, von Wachter and Heisz (2005) find that graduates entering a labor market in a recession have large earnings losses and take approximately 10 years to reach the same footing as graduates entering during normal times.⁵ Oyer (2006) finds that in the market for academic economists, initial placement at a school one rank higher leads to work at an institution ranked .6 places higher 3 to 15 years in the future.

In this paper, we construct a model of an entry-level professional labor market (such as those for lawyers, MBAs, academics, and others) where applicants have private information about their abilities and firms can interview applicants at a cost to uncover that information. In the model, we find a large inefficiency in the hiring process that we call *information-based unemployment*. This phenomenon arises when a firm decides not to interview (and therefore rejects) an applicant who has not previously received an offer in the hiring process. The lack of an offer creates a bad signal about

¹From Staffing.org's 2006 survey "Recruiting Metrics and Performance Benchmark Report".

²From the same survey. We present two caveats about the data on time spent recruiting. First, it does not apply solely to entry-level professional workers. Second, it is a rough measure of the actual cost of time. For example, if multiple Senior Partners from a consulting firm dedicate a day to recruiting, the opportunity cost could be very large. Of course, we are not including travel costs or physical expenses either.

³"Net fails to oust networking: Headhunters", by Michael Dempsey, *Financial Times*, July 16, 2003. To get a sense of how much money this is per recruit, an MBA graduating from a top 50 program in 2006 earned \$94,447. Based on authors' tabulation from data gathered in U.S. News & World Report's Full Time Business School Rankings 2007.

⁴Farber and Gibbons (1996) and Altonji and Pierret (2001) demonstrate that education level matters less relative to inherent ability as a worker's career develops. This implies that the asymmetric information problem can be important for entry level positions.

⁵Kahn (2007) finds that negative wage effects persist beyond 10 years and also provides evidence on mismatch between workers and jobs.

what previous interviews had uncovered about the applicant. This unemployment could, and in some cases, should be avoided, since the rejected applicant may actually be a good match for the firm. We demonstrate that these inefficiencies may be so large that *randomly matching applicants to firms can achieve a larger surplus than the interview process*.

Information-based unemployment is a robust feature of the interview process - it occurs whether job offers are open or exploding, no matter how many rounds of interviewing are added to the hiring process, and for different information structures. These results are relevant for any matching market that involves costly screening, such as those where lenders give money to borrowers, individuals seek to purchase homes, and the market for corporate control.

We also prove that efficiency in the market can be achieved through market design. Both a mechanism with transfers and one without transfers implement the optimal match. Market design, once limited to more centralized markets such as “The Match” for residents to hospitals,⁶ has become an issue of great relevance. Roth and Xing (1994) describe a multitude of attempts to regulate matching markets (Federal Court Clerkships, MBA job market, Clinical Psychology Internships, College Football Bowls among others) by instituting timing rules, restrictions on types of offers, and matching mechanisms. Roth, Cawley, Levine, Niederle and Siegfried (2007) have redesigned aspects of the graduate economics job market, adding the possibility of signaling interest to universities as well as a post-market “job scramble” as a final market clearing stage. Some business schools even conduct auctions for interviews, using a fixed budget constraint to make bidding costly.⁷

Our model is simple. Firms have observable productivities, applicants have abilities that are private information and matches create a surplus that depends monotonically on both and is split proportionally by the firm and applicant. In order to find out applicant abilities, firms can interview them at a cost. There is an interview schedule in which an applicant is matched to one firm in the first period and another firm in the second period. Although we consider a two-period model, our results are robust to adding additional periods.

There is a large literature on labor market matching with perfect information (for example, see Kelso and Crawford (1982)). Several recent papers have examined decentralized labor markets where information about worker

⁶For a description, see Roth (2003).

⁷For a theoretical analysis, see Sönmez and Unver (2007).

abilities is *symmetric* between firms and workers and is gradually revealed over time. Roth and Xing (1994) examine unraveling in such a model, allowing for centralized matching to take place in the final period. Unraveling is also the focus of Li and Rosen (1998), who analyze a two-period model with risk averse agents.⁸ Niederle and Roth (2007) theoretically and experimentally study a particular nine period market allowing for both exploding offers and open offers. They find that exploding offers promote early and dispersed transactions and that open offers create late and thick markets.

Two current papers allow for asymmetric information in decentralized labor markets.⁹ Niederle and Yaariv (2007) analyze an infinite-horizon model that allows for both exploding and open offers and different degrees of information asymmetries. Their model differs from ours in that it allows firms to make offers to any worker and does not have any costly discovery of information (as we do through interviews). Moreover, their focus is on sufficient conditions for the existence of equilibria that implement the stable match. Chakraborty, Citanna, and Ostrovsky (2007) examine matching when firms have private imperfect signals about each worker’s type. They prove that there is no mechanism which can get truthful revelation from firms and match workers and firms efficiently in the sense that there are no blocking worker-firm pairs after the match. Since they are concerned with optimality, they don’t characterize what inefficiencies may arise.¹⁰ We are actually able to find optimal mechanisms for our environment for two reasons. First, in our first mechanism we allow workers to reveal their own types through prices, which eliminates the firms’ incentive problems. Second, the signals that firms receive are perfect in our model which doesn’t allow room for blocking pairs.

This paper is organized as follows. In Section 2, we analyze a simple model with two firms and two applicants. In Section 3, we generalize the results to multiple firms and applicants. In Section 4, we look at welfare. In Section 5, we examine the robustness of the information structure. In Section 6, we look at correcting market inefficiencies through market design. In Section 7, we conclude.

⁸Li and Suen (2000), Suen (2000), and Li and Suen (2004) all extend the model of Li and Rosen (1998) to further examine unraveling. Damiano, Li, and Suen (2005) examine unraveling in a search environment where the horizon is finite.

⁹Lee and Schwarz (2007a and 2007b) examine information acquisition about candidates through interviews when matching is centralized.

¹⁰Although they do speculate that in a dynamic model such as ours, the signaling effect of offers can cause inefficiencies.

2 A Simple Model with Two Applicants and Two Firms

We start by examining the case of two firms and two applicants. In Section 3 we show that the analysis of this simple case extends to the general case of multiple firms and applicants.

There are two firms $i = 1, 2$ of publicly observable productivity f_1 and f_2 , where $f_2 > f_1 > 0$, and two applicants, $j = 1, 2$, of privately observable productivity $x_j \in \{L, M, H\}$, where $H > M > L > 0$. The realization of the types of the two applicants are independent and determined by the probabilities p_L , p_M , and p_H , which are all positive and sum to one.

The game has two periods. The timing is as follows. At the start of the game, nature draws the types of the two applicants and the order in which they are matched with the two firms. In period 1, the firms observe the order of matches and the type of the applicant they are first matched with, but not the type of the other applicant.¹¹ For notational clarity, we define the matches in period 1 as firm 1 with applicant 1 and firm 2 with applicant 2. After observing the applicant's type the firms decide whether or not to make the applicant they are matched with an offer. The applicants decide whether or not to accept the offer. In period 2, the firms observe all the offers and responses from the first period. The firms are matched with the applicants they did not match with in period 1. Conditional on their information, each firm decides whether to interview the applicant it is matched with in the second period at a cost of $\alpha c > 0$, where $\alpha \in (0, 1)$. The firm then chooses whether to make the applicant an offer or not. We also allow firms (i) to make offers to applicants they are matched with even if they did not interview them and (ii) to make their period 1 applicants an offer in period 2 if they had not done so already.

To summarize, the interview schedule for the two applicant-two firm game is:

	Firm 1	Firm 2
Period 1	applicant x_1	applicant x_2
Period 2	applicant x_2	applicant x_1

We assume that the surplus from a match is multiplicative: a firm with productivity f_i who hires an applicant of ability x_j creates a surplus $\pi_{ij} = f_i x_j$. The players split the surplus from the match: firms get $\alpha \pi_{ij}$ and

¹¹Hence we assume zero interview costs in period 1. This adds tractability and makes it feasible for some hiring to occur.

applicants get $(1 - \alpha)\pi_{ij}$. This rule ensures that firms prefer being matched with higher ability applicants, applicants prefer being matched with higher productivity firms, and that in a frictionless market the first best match is one of assortative matching. The results would be the same for monotonic transformations of the surplus, $\pi_{ij} = g(f_i)h(x_j)$, where $g', h' \geq 0$. We take the sharing rule to be exogenous, but it clearly could result from some bargaining process. We assume that there is a threshold or outside option for firms, which they receive should they not hire anyone equal to $\alpha f_i t$. The value of the threshold is common across firms and $H > M > t > L$, implying that neither firm would willingly hire a type L applicant.¹² Applicants also have a reservation payoff. An applicant of productivity x_j receives $(1 - \alpha)\bar{w}x_j$ from not being hired.¹³ We assume that working is preferable to not working, i.e. $\bar{w} < \min\{f_i\}$. Finally, we assume that the structure of the game is common knowledge to all participants.

Firms can make open offers. We define an open offer as an offer extended by the firm to an applicant in period 1 that can be held by the applicant in period 2. The applicant can accept the held offer should it be more attractive than their period 2 situation. In a working paper version of this paper (Josephson and Shapiro (2008)), we show that our results also hold for an exploding offers environment (i.e. where applicants can't hold offers).

We restrict the parameters to look at specific equilibria of the hiring game. We assume that the following conditions hold for both firms:

$$f_i \left(\frac{p_L L + p_M M}{p_L + p_M} \right) < f_i t, \quad (\text{A0})$$

$$f_i \left(\frac{p_L t + p_M M}{p_L + p_M} \right) - c < f_i t, \quad (\text{A1})$$

$$f_i((1 - p_H)M + p_H H) - c > f_i M. \quad (\text{A2})$$

Assumption 0 says that the firm would prefer to go unmatched rather than to hire an applicant that is not of high type without interviewing her. Assumption 1 says that the firm would prefer to go unmatched rather than interview an applicant when it doesn't have the possibility of hiring a high

¹²Nevertheless, L applicants may still be hired in the model, when firms decide to hire without interviewing. Alternatively, a model where firms make mistakes in their interview process with small probabilities would have similar results and have L applicants hired in equilibrium.

¹³Hence firms (applicants) have reservation payoffs that increase in their productivity (ability). This is not important for the results.

type. Assumption 2 says that firms who had a type M applicant in period 1 would prefer to interview in the second period in order to see if they could do better. In addition to these assumptions, we will for expositional purposes assume that if a firm is matched with an applicant of the same type in periods one and two, and it can hire either of them with probability one, then it will always prefer the latter. These assumptions pin down parameters for which information-based unemployment will occur:

Proposition 1 *In any Perfect Bayesian Equilibrium that satisfies A0-A2:*
i) If $x_2 = H$, firm 2 will hire applicant 2 either in period 1 or 2. If $x_2 = M$ or L , firm 2 will either interview applicant 1 and hire applicant 1 if she is of type M or H or hire her without interviewing.
ii) In period 1, firm 1 will either not make any offers to applicant 1 or mix between making offers and not when $x_1 = M$ and H . In period 2, firm 1 never interviews applicant 2 or makes her an offer without interviewing her.

The proof is in the appendix.

In this model, firm 1 will never be able to hire applicant 2 if she is of type H . This implies (by A1) that it finds it too costly to discover whether the applicant is of type L or M and (by A0) that it will not make her an offer without interviewing her. If the draw of applicant types is such that $x_1 = H$ and $x_2 = M$, then it follows from Proposition 1 that firm 2 will hire applicant 1 (by A2), but that applicant 2 will remain unemployed.

Corollary 1 *If $x_1 = H$ and $x_2 = M$ and A0-A2 hold, in any equilibrium there is unemployment.*

We refer to the unemployment of M types caused by the information asymmetry as *information-based unemployment*. Specifically, information-based unemployment occurs when a firm would have hired an applicant had it known the applicant's type, but both go unmatched due to asymmetric information. Adding more periods to this game would not change the outcome - firm 1 would still refuse to interview or make an offer to applicant 1 because its information set would not change. Moreover, as we will show in Section 3, this effect is also robust to introducing more firms and applicants. In Section 4, we will analyze the welfare consequences of information-based unemployment.

2.1 Schedule-Based Unemployment

Suppose that there are now three firms with productivities $f_3 > f_2 > f_1 > 0$ and three applicants who we will assume to have drawn types (unobserv-

able to the firms) $x_1 = H$, $x_2 = H$, and $x_3 = M$. In an ideal job market, all three applicants should match as they are above the thresholds of the firms. However, in our frictional market, this may not occur. We defined information-based unemployment as unemployment due to asymmetric information and interview costs. *Schedule-based unemployment* arises because the interview schedule allocates applicants randomly, creating potential for mismatch.¹⁴ Consider the following interview schedule:

	Firm 2	Firm 3	Firm 1
Period 1	$x_2 = H$	$x_3 = M$	$x_1 = H$
Period 2	$x_3 = M$	$x_1 = H$	$x_2 = H$

Even with zero interview costs, this schedule will result in unemployment. Firm 3 would hire applicant 1 since it knows that she prefers its offer to that of firm 1. Firm 2 would hire applicant 2 for the same reason. This however, would leave firm 1 without an applicant and applicant 3 without a match, even though both of them would prefer to be matched with each other. This is a clear situation where the unemployment is caused by the interview schedule. Moreover, the problem could be solved simply, by adding another period. Such a remedy corresponds to recommendations by Roth, Cawley, Levine, Niederle and Siegfried (2007) for the economics job market (using the “job scramble” to clear the market).

Nevertheless, adding another period would not solve the problem if there were positive interview costs.¹⁵ If assumption A2 holds, firm 3 will wait until the second period to hire, and then hire applicant 1. Firm 2 makes an offer to applicant 2 that is then accepted and doesn’t interview in period 2. Firm 1, on the other hand, doesn’t get either of its two applicants and applicant 3 remains unmatched. Therefore schedule-based unemployment still exists with positive interview costs. If another period were added where firm 1 would be scheduled to meet x_3 , would the inefficiency disappear? If A0 and A1 hold, the answer is no. Firm 1 can infer that applicant 3 is not type H by the fact that firm 3 did not extend an offer to applicant 3. From A1, firm 1 doesn’t find it worthwhile to spend the interview cost on an applicant who isn’t type H , and A0 guarantees it doesn’t want to hire

¹⁴In the matching literature, this could be called a congestion effect. However, we will show that it interacts with the asymmetric information to create more than a standard congestion effect.

¹⁵In the next section we analyze the hiring game where there are more than two firms and two applicants. The equilibrium we discuss here is covered by Proposition 2 in that section.

without interviewing. Hence, information-based unemployment makes the schedule-based unemployment robust to changes in the market.

3 The General Model

We now generalize the model to F firms and X applicants in order to illustrate that information-based unemployment exists in a more realistic environment. Consider the general case with firms $i = 1, \dots, F$ of heterogeneous productivities f_1, \dots, f_F , with $F \geq 2$. Applicants are labeled by $j = 1, \dots, X$ and can still be one of three types: L, M , or H . We assume that applicants are allocated according to an interview schedule which is random but has the properties that (i) no applicant interviews with the same firm twice, (ii) only one applicant is allocated to each firm in each period, and (iii) if there are less or equal number of agents on one side of the market, they should all be matched. We maintain assumptions A0, A1, and A2 for all firms.

Proposition 2 *In the general model where A0-A2 hold:*

- i) In any Perfect Bayesian Equilibrium, firms only interview their second-period applicant or make her an offer if she was interviewed by a lower productivity firm or unmatched in period 1.*
- ii) In any Perfect Bayesian Equilibrium with $F \leq X$, there exists a draw of applicant productivities such that there will be at least one M type unemployed.*

The proof is in the appendix.

This proposition yields two key insights. First, not all firms are interviewing. The fact that a firm does not interview or hire if it receives an applicant from a more productive firm in the second period is a consequence of A0 and A1 - the inference is that the applicant is not that good. However, the fact that a firm interviews if it receives an applicant from a less productive firm is not obvious and a consequence of A2, which states that a firm with an M (and thus also an L) applicant in period 1 is willing to interview in period 2.

The second insight demonstrates that unemployment is a phenomenon that can arise in the general model. Consider the situation where $F = X$ (unemployment trivially occurs if $F < X$). Define a local maximizer to be a firm that has a higher productivity than both the firm it gives an applicant to in period 2 and the firm that it receives an applicant from in period 2. Information-based unemployment occurs when an applicant of type M is not hired by the local maximizer in period 1 and then does not get interviewed

(or made an offer) by the firm it is matched with in period 2. Since at least one local maximizer must exist for any set of firms, there is always a draw of applicant types such that information-based unemployment will arise in any such labor market. Moreover, information-based unemployment may exist not just where there is a local maximizer, but for any increasing sequence of firms, i.e. where firm i receives an applicant in period 2 that was matched with a more productive firm in period 1, and gives its first period applicant to a less productive firm in period 2. The existence of schedule-based unemployment, on the other hand, depends on the configuration of firms and applicants.

Interestingly enough, although more applicants than firms leads to unemployment, it may prevent information-based unemployment. Consider the case of two firms and four applicants. If the two firms do not interview any applicants in common, there is no room for adverse selection.

On the other hand, when there are more firms than applicants (i.e. $F > X$), information-based unemployment is possible, but not guaranteed. First, consider the case of three firms with productivities $f_3 > f_2 > f_1$, and two applicants. The first applicant is of type H and matches with firm 1 in period 1 and firm 3 in period 2, and the second applicant is of type M and matches with firm 3 in period 1 and firm 2 in period 3. In this case, the best firm will hire H , but the M applicant will remain unemployed because of the information problem. Second, consider the case of two firms and one applicant. In this case, the firm of highest productivity will always end up hiring the applicant if she is not of type L , implying no unemployment.

4 Welfare

It is clear that the interview process that we describe does not achieve the first best of assortative matching, nor does it reach the constrained first best of matching using the preset interview schedule when there is full information about applicants' abilities. When discussing welfare, we then want to know how poorly the market performs. In this section, we show that the performance of the interview process can be so poor that it may not even beat the situation where there are no interviews and matching is random.

We begin by comparing the interview process to a slightly better benchmark, random matching with interviews. This essentially eliminates the second period of the interview process, and is random matching except for the fact that type L applicants can be discarded by firms.

Proposition 3 *Random matching with interviews can achieve a better ex-*

pected surplus than the interview process.

Consider the case of two firms, $i = 1, 2$, with productivities $f_2 > f_1$, and two applicants. To make things as clear as possible, we will focus on the equilibrium of this game where firm 1 makes no offers¹⁶ and firm 2 interviews firm 1's candidate when it doesn't have an H type in the first round.¹⁷ There are four possible applicant draws where there is a difference between the final surplus with random matching with interviews and the interview process: (L,M), (M,M), (M,H), and (L,H), where the first element corresponds to the applicant assigned to firm 2 in period 1. The expected difference in total surplus between the two markets is:

$$\begin{aligned}
& ETS(\text{Random with Interviews}) - ETS(\text{Interview}) \\
= & -(f_2 - f_1)(p_{LP_M}(M - \alpha t) + p_{LP_H}(H - \alpha t) + p_{MP_H}H) \\
& + p_M^2(f_1M - (\alpha f_1 t + (1 - \alpha)\bar{w}M)) + p_{MP_H}(f_2M - (\alpha f_1 t + (1 - \alpha)\bar{w}M)) \\
& + (1 - p_H)\alpha c.
\end{aligned}$$

We can break this difference into three parts. On the first line, the difference is negative, since the interview process performs a screening role and matches better applicants to better firms. On the second line the difference is positive, since the interview process causes information-based unemployment for surplus producing M applicants. Lastly, the interview cost obviously weighs against interviewing.

It is clear that this difference is positive for sufficiently low $f_2 - f_1$, since that minimizes the negative part of the expression. The intuition for why random matching with interviews can be better when $f_1 - f_2$ is lower is straightforward. Lowering heterogeneity among firms makes the surplus increase from screening less meaningful. Given that screening is costly both

¹⁶Recall that other equilibria involve firm 1 mixing between making offers and not making offers to M and H types in period one. If firm 2 interviews firm 1's candidate after observing "no offer" in these mixed strategy equilibria and in the equilibrium where no offers are made, the only difference is that the interview cost is saved some fraction of the time in the mixed strategy equilibria (since upon observing "offer", firm 2 hires without interviewing). If firm 2 hires without interviewing firm 1's candidate after observing "no offer" in these equilibria and the one where no offers are made, the outcomes are exactly the same.

¹⁷Firm 2 might prefer to hire firm 1's first period candidate without interviewing (depending on the parameters). In this case, the analysis also goes through. The only difference is that instead of having the interview cost favor random matching, there is a cost of firm 2 getting stuck with an L type that favors random matching.

in terms of causing information-based unemployment and the actual cost of interviewing, random matching with interviews can dominate in terms of welfare.¹⁸

Now suppose we compare the interview process with random matching where interviews aren't permitted.

Proposition 4 *Random matching can achieve a better expected surplus than the interview process.*

Once again we consider the two firm case (where firm 1 makes no offers in period 1). We now need to consider additional period 1 applicant draws that will differ between the interview process and random matching since under random matching the L types won't be screened. The expected difference in total surplus between the two markets is:

$$\begin{aligned}
& ETS(Random) - ETS(Interview) \\
= & -(f_2 - f_1)(p_L p_M M + p_L p_H H + p_M p_H H) \\
& + p_M^2(f_1 M - (\alpha f_1 t + (1 - \alpha)\bar{w}M)) + p_M p_H(f_2 M - (\alpha f_1 t + (1 - \alpha)\bar{w}M)) \\
& + p_L(f_2 L + f_1 L - 2(\alpha f_1 t + (1 - \alpha)\bar{w}L)) - p_L^2 \alpha (f_2 - f_1) t \\
& + (1 - p_H)\alpha c.
\end{aligned}$$

This difference consists of four parts. The second part and the last part are exactly the same as when the random matching with interviews model was used. The first part is almost the same as well, omitting a part due to the fact that firms can't screen in random matching. The third part is the truly new part and arises because under random matching firms end up with L types. It reflects the difference between the match with an L type and the alternative, where the applicant and firm get their outside options.¹⁹

In order to prove that random matching can yield a higher surplus, we will prove that parts one and three of the expression above can get small or become positive for certain parameters (and without violating any

¹⁸Proposition 3 holds also when $\alpha = 1$. Firm 1's decision not to interview an applicant who has no offer is then efficient, but Firm 2's decision to interview its period 2 candidate when it has an M or L candidate in period 1 exerts a negative externality on firm 1. This implies that for a small $f_2 - f_1$, our result that random matching with interviews is better than the interview process still holds. We thank Tomas Sjoström for raising this point.

¹⁹The third line is the simplified version of adding up the surplus from all of the states in which a firm gets stuck with an L applicant. The second term of the expression reflects that fact that when both applicants are L , firm 2 won't be matched even in the interview process and there is some extra surplus lost.

assumptions). We already have shown that part one can be made small by decreasing the heterogeneity between firms, $f_2 - f_1$. Part three can be made small or even positive by decreasing α . In the extreme, if α was set equal to zero, the expressions would be positive. This implies that if firms receive less of the surplus their mismatch becomes less important, and the gain from the applicant's point of view of matching can be larger. Notice that reducing α doesn't violate any of our assumptions.²⁰

It is clear that the two results in this section hold for a range of parameter values. Furthermore, if we added more firms and applicants, as long as there was information-based or schedule-based unemployment for some draw, for sufficiently low firm heterogeneity, the expected surplus will be lower with two rounds of interviews than with one round. If, in addition, the firms' share of surplus is sufficiently low, then the expected surplus is lower with two rounds of interviews than with random matching.

5 Changing the Information Structure

In the general model above, we have assumed that firms know exactly which firms are interviewing each applicant in each period, i.e. the interview schedule and firm productivities are common knowledge. Although this makes the model more tractable, this may not be true in markets where there are more than a few players. A firm may not know with whom the applicant is scheduled to interview in the next period, with whom the applicant has previously interviewed, or if she has received any offers. Indeed, an applicant may not have incentives to reveal this information either. Hence in this section, we look at an example where these assumptions are relaxed and prove that information-based and schedule-based unemployment may still exist.

Consider an environment where firms know the distribution of firm productivities, but do not observe which firms are interviewing which applicants or if any offers are made in the first period. To keep things simple (firms now have to take expectations over what the whole sequence of firms will do), our example will involve only 3 firms and 3 applicants.²¹ We assume it is common knowledge that the three firms have productivities $f_3 > f_2 > f_1 > 0$, but each firm only knows its own productivity.

Proposition 5 *In the unobservable interviews game where A0-A2 hold, in any Perfect Bayesian Equilibrium:*

²⁰ Alternatively, we could have made L larger or \bar{w} and p_L smaller to minimize part three. However, the assumptions place strict constraints on manipulating these parameters.

²¹ We need at least three firms in order to make the non-identifiability of firms have bite.

- i) Firm 3 makes its first-period applicant an offer in period 1 or 2 if she is of type H, and interviews its second-period applicant or makes her an offer without interviewing otherwise.*
- ii) Firm 1 never interviews or makes an offer to its second-period applicant.*

The proof is in the appendix.

The intuition for this result is that although firm 3 does not know from which firm it will receive an applicant in period 2, it knows it has the highest productivity of all firms and will win any bidding competition. Likewise, although firm 1 does not know from which firm it will receive an applicant in period 2, it knows it has the lowest productivity and will lose any bidding competition. Hence, these two firms will act like the firms in the previous section with two firms and two applicants. Firm 2, on the other hand, will find it equally likely to receive an applicant from firm 1 and firm 3 and will choose to interview in period 2 if and only if this gives a higher expected payoff than not interviewing.

Proposition 5 immediately implies the following Corollary.

Corollary 2 *In the unobservable interviews game where A0-A2 hold, in any Perfect Bayesian Equilibrium and for any interview schedule, there exists a draw of applicant productivities such that an applicant of type M will be unemployed.*

Consider the following example:

	Firm 1	Firm 3	Firm 2
Period 1	$x_1 = H$	$x_3 = M$	$x_2 = H$
Period 2	$x_3 = M$	$x_2 = H$	$x_1 = H$

By Proposition 5, firm 3 will hire applicant 2 and firm 1 will not interview applicant 3. Whether firm 2 interviews applicant 1 or not depends on the parameters (but it will not make applicant 1 an offer without interviewing). If firm 2 interviews applicant 1, it will hire her and applicant 3 will be unemployed while firm 1 is unmatched. This is an example of information-based unemployment in this model. If, on the other hand, firm 2 does not interview applicant 1, this applicant will be hired by firm 1, and applicant 3 will be unemployed while and firm 2 is unmatched. This is an example of schedule-based unemployment.

6 Market Design

In this section, we use the tools of mechanism design theory to try to correct inefficiencies in the interview process. We will first show that if we allow for payments from applicants, then the efficient assortative match²² can be achieved using a modified Vickrey-Clarke-Groves (VCG) mechanism. We then demonstrate that there exists a mechanism that can achieve efficiency without any transfers, by incorporating features of the market.

6.1 A VCG Mechanism

The mechanism design problem in our setting is similar to the assignment problem of applicants with risk-neutral preferences to positions considered by Leonard (1983). He developed a mechanism that is a special case of a Vickrey-Clarke-Groves mechanism which works in our setting as well, subject to two amendments. The reasons for making these amendments is that Leonard (1983) does not allow for reservation values and that he assumes an equal number of applicants and firms.

We can modify our model in two ways so that it fits the requirements of Leonard’s (1983) mechanism. First, we will assume that in addition to the L, M , and H types of applicants in our standard model, there are F “reservation applicants” of type t , where $L < t < M$ as above, whose types are known. If an applicant of type t is assigned to a firm, this is equivalent to saying that the firm is not matched with any applicant. Furthermore, type announcements are restricted to the set $\{L, M, H\}$, i.e. no one can announce that they are type t . In a similar vein we will assume that there are X “reservation firms” of productivity \bar{w} where, as above, $\bar{w} < \min\{f_i\}$. If an applicant is assigned to a reservation firm, this is equivalent to saying that the applicant is not matched with any firm. Let \mathbb{X} be the set of all applicants of types L, t, M , and H , and let \mathbb{F} be the set of firms of productivities \bar{w}, f_1, \dots, f_F . Our assumptions imply that $|\mathbb{F}| = |\mathbb{X}| = X + F$.

Finally, an applicant j receives a surplus from matching with a firm i of $(1 - \alpha)f_i x_j - p$ where p is the payment²³ determined by the following

²²We are assuming for this section that $f_i L < \alpha f_i t + (1 - \alpha)\bar{w}L$, i.e. it is more efficient for firms and applicants to remain unmatched if the applicant is an L type. This depends on α . If this were not true, the match that we implement in the mechanisms would be assortative, but not the most efficient. Moreover, if we implemented the most efficient match where the constraint didn’t hold, we would violate ex-post individual rationality, and potentially interim individual rationality, since the firms would not want to be matched with L types.

²³Whether the payments go to the firms or the third party will not affect incentives.

mechanism:

1. Each non-reservation applicant j is asked to announce a type $\tilde{x}_j \in \{L, M, H\}$.
2. Sequentially and in descending order of productivity, every firm in \mathbb{F} is then assigned to the applicant of highest (reported or known) type remaining in \mathbb{X} . If, at some stage, there are multiple applicants with the highest type, then an applicant drawn at random among them is assigned to the firm with highest productivity among the remaining ones.
3. Each non-reservation applicant $j \in \mathbb{X}$ who was matched to a firm $i \in \mathbb{F}$ has to make a payment p equal to $(1 - \alpha)$ times the difference between
 - (a) the total (announced) surplus for all applicant-firm pairs if the applicants in $\{\mathbb{X} \setminus j\}$ are assigned to the firms in \mathbb{F} according to the procedure in stage 2,²⁴ and
 - (b) the total (announced) surplus for all applicant-firm pairs if the applicants in $\mathbb{X} \setminus j$ are matched with the firms in $\mathbb{F} \setminus i$ according to the procedure in stage 2.

This mechanism achieves the efficient assortative match as a Bayesian equilibrium in dominant strategies (for a proof see Leonard (1983)). In the mechanism, type L applicants are unmatched (since they are assigned to reservation applicants) and pay zero transfers.

This mechanism satisfies ex-post participation constraints for both firms and applicants in the sense that each participant receives at least his reservation utility. To see this, note that all firms receive at least their reservation utility in this mechanism as they will either be unmatched or matched with an applicant of productivity M or H . Moreover, all applicants obtain a utility greater than or equal to their reservation utility, since announcing type L in step 2 – and thereby remaining unmatched – is a dominated strategy for M and H types (and a dominant strategy for L types).

6.2 A Mechanism without Transfers

The previous mechanism achieved the first best in a simple manner, essentially creating prices that would induce incentive compatibility. However, it

²⁴A firm not matched with either a reservation applicant or regular applicant is assumed to have a surplus of zero.

may be desirable to see if a mechanism can achieve a similar outcome without transfers and instead using the interview technology introduced above, where the first interview is free while the second incurs a cost of αc (of course, the first best involves this cost never being incurred). The difficulty in constructing such a mechanism is that we must rely on firms to solicit and reveal information truthfully, giving additional incentive constraints. Nevertheless, we can implement the first-best solution as a Perfect Bayesian Equilibrium with the following mechanism:

1. Each applicant j is asked to announce a type $\hat{x}_j \in \{L, M, H\}$ to a third party.
2. All applicants who announced L are placed in a pool of *unmatched applicants*.
3. Take the unmatched firm with the highest productivity, match it with the applicant of the highest announced productivity (randomize if there are multiple applicants of this productivity), continue with the next highest firm until all firms are matched or there are no more applicants reporting H or M . If, at the end of this procedure, there are applicants left, they are placed in the pool of unmatched applicants.
4. Have the firms interview the applicants they are matched with. Each firm j matched with an applicant reports a type for the applicant $\check{x}_j \in \{L, M, H\}$ to a third party.
5. If the firm's report doesn't match the applicant's reported type ($\hat{x}_j \neq \check{x}_j$), the applicant is placed in the pool of *misreporting applicants*.
6. If an applicant is taken out in step 5, repeat step 3 for all firms and the applicants not in the unmatched and misreporting pools.
7. Allow the firms that are matched with applicants at the end of step 6 to hire them. If they are hired, the applicant and the firm split the surplus generated according to the sharing rule α . If they are not hired, they are placed in the pool of unmatched applicants.
8. If there are unmatched applicants and unmatched firms, randomly assign applicants first from the unmatched pool and thereafter from the misreporting pool among the remaining firms. Let each firm matched in this way know from which pool its applicant was drawn and allow it to interview and/or hire the applicant.

Proposition 6 *In the above mechanism, there is a Perfect Bayesian Equilibrium where all firms and applicants report truthfully and contract assortatively.*

The proof is in the appendix.

This mechanism achieves the assortative match with zero interview costs. This is accomplished with zero transfers and using the firms' interviewing ability to provide incentives for applicants to state their types truthfully. In particular, all applicants of type H and M and all firms (except possibly the firm with the lowest productivity if $X = F$) have strict incentives to announce truthfully. The mechanism also satisfies ex-post participation constraints in the sense that it gives each participant a payoff greater than or equal to his reservation payoff.

7 Conclusion

Understanding decentralized labor markets is critical to understanding the dynamics of unemployment and mismatch. In a simple model describing the interview process for professional labor markets, we have pointed out potentially large inefficiencies, chief among them information-based unemployment. Information-based unemployment occurs when applicants' types are private information and firms decide not to interview or hire an applicant who previously had an interview but no job offer to show from it. This could cause good applicants to go unemployed and productive vacancies to go unfilled. Randomly matching applicants to firms may be more productive than this interview process. We detail two mechanisms that can make the market efficient.

Our work suggests several directions for future research. First, changing the setting to allow for strategic wage setting and idiosyncratic preferences among firms and applicants are natural extensions. Second, analyzing interview markets for non-entry level applicants poses interesting challenges. Lastly, recent practical contributions by Roth, Cawley, Levine, Niederle and Siegfried (2007) to the economics job market hold significant promise, and are worth examining in further detail for their application to other markets.

Appendix

Lemma 1 *In any Perfect Bayesian Equilibrium of the general model, a firm with a first-period applicant of type H who is matched with no firm or a firm*

of lower productivity in the second period, hires this applicant – either in the first or the second period.

Proof. Let firm i denote a firm whose first-period applicant j , of productivity $x_j = H$, is matched with no firm or a firm of lower productivity in the second period. First note that since applicant j knows the productivity of the firms it will be matched with in the first and second period, it will always accept an offer from firm i , either in the first or the second period. Second, it is clear that firm i will never interview a possible second-period applicant $j + 1$ since it would thereby incur the interview cost without any possibility of being matched with a more productive applicant. Third, there is no equilibrium where firm i hires applicant $j + 1$ without interviewing. If firm i were to hire applicant $j + 1$ without interviewing, it would have to have the equilibrium posterior beliefs that $x_{j+1} = H$ with probability one. Such beliefs are only possible if there is a firm $i + 1$ interviewing applicant $j + 1$ that makes her an offer in the first period with positive probability iff she is of type H or that makes her an offer iff she is not of type H . However, neither can be an equilibrium strategy for firm $i + 1$ since it could then profitably deviate by not making an offer if $x_{j+1} = H$ (or making an offer if $x_{j+1} = H$, respectively) in the first period and thereby preventing firm i from hiring the applicant in the second period. ■

Lemma 2 *In any Perfect Bayesian Equilibrium of the general model, a firm with a first-period applicant who is not of type H and a second-period applicant who was unmatched or matched with a firm of lower productivity in the first period, either interviews its second-period applicant or hires her without interviewing.*

Proof. Let firm i be a firm with a first-period applicant j of productivity $x_j = \emptyset, M$ or L (where \emptyset represents no applicant) and a second-period applicant $j + 1$, who was interviewed by a less productive firm $i + 1$ or no firm in the first period. It follows trivially from A2 and A0 that firm i interviews applicant $j+1$ (or makes her an offer without interviewing) if she is not interviewed by any firm in period 1. The same argument applies if she is interviewed by a less productive firm $i + 1$ that makes an offer to all types or applicant, no type of applicant, or randomizes between these two strategies in period 1. Finally, consider the case when applicant $j+1$ is interviewed by a less productive firm $i + 1$ that makes a first-period offer with a probability that depends on the type of applicant $j + 1$. Suppose that there is an equilibrium such that firm i with positive probability neither

interviews nor makes an offer without interviewing after observing action Y (an offer or no offer) by firm $i + 1$ in the first period. Then firm i must weakly prefer not to interview applicant $j + 1$ and not to hire her without interviewing after observing action Y . Moreover, by A2, it must strictly prefer to interview her after observing the complementary action Y^C . This means that in equilibrium, firm $i + 1$ must employ Y whenever matched with an applicant of type $x_{j+1} = M$ or H , thereby making sure that firm i does not pursue applicant $j + 1$. However, this contradicts the fact that firm j weakly prefers not to interview after observing action Y . ■

Lemma 3 *In any Perfect Bayesian Equilibrium of the general open offer game, a firm never interviews or makes an offer to a second-period applicant who was matched with a firm of higher productivity in the first period.*

Proof. By Lemma 1, a firm i receiving an applicant $j + 1$ from a more productive firm $i + 1$ in the second period will never be able hire this applicant if $x_{j+1} = H$. If $x_{j+1} = M$, she will be able to hire this applicant only if firm $i + 1$ does not make her an offer. This is conditional upon $i + 1$ being matched with another applicant $j + 2$ (who is identical to j in the case of only two firms) in the second period. More specifically, it occurs either if the parameters are such that firm $i + 1$ makes an offer without interviewing to applicant $j + 2$ in the second round or if she interviews $j + 2$ and $x_{j+2} = M$ or H . Hence, firm i 's incremental expected payoff from interviewing applicant $j + 1$ is at most $\alpha f_j p_M (M - t) / (p_L + p_M) - \alpha c$ and from making her an offer without interviewing at most $\alpha f_j (p_M (M - t) + p_L (t - L)) / (p_L + p_M)$. The first is negative by A1 and the second by A0. ■

Proof of Proposition 1

(i) Follows from Lemmas 1 and 2.

(ii) First note that firm 1 will never make an offer to applicant 1 if $x_1 = L$. Since, by Lemma 1, firm 2 will hire applicant 2 if $x_2 = H$ in any equilibrium, there is a positive probability that such an offer would be accepted, giving a strictly worse payoff than the outside option. There are two possibilities. Either (a) firm 1 makes applicant 1 an offer with positive probability in the first period if $x_1 = M$ or H or (b) firm 1 never makes an offer in period 1.

(a) By Lemma 2, when $x_2 \neq H$, firm 2 will make applicant 1 an offer without interviewing if it observes an offer in the first period and either make an offer to applicant 1 or hire her without interviewing if it does not observe any offer. This means that its expected payoff from either interviewing or

making an offer to applicant 1 conditional upon not observing any offer must be at least as large as that of hiring applicant 2 (if $x_2 = M$) or the outside option (if $x_2 = L$). Letting r_M denote the probability that firm 1 does not make an offer in period 1 conditional upon $x_1 = M$, and letting r_H denote the probability that firm 1 does not make an offer in period 1 conditional upon $x_1 = H$, at least one of the following two conditions must be fulfilled:

$$f_2\left(\frac{1}{p_L + r_{MPM} + r_{HPH}}\right)(p_L M + r_{MPM} M + r_{HPH} H) - c \geq f_2 M$$

$$f_2\left(\frac{1}{p_L + r_{MPM} + r_{HPH}}\right)(p_L L + r_{MPM} M + r_{HPH} H) \geq f_2 M.$$

The first condition says that firm 2 will interview its period 2 applicant. The second says that it will hire its period 2 applicant without interviewing. For r_H sufficiently close to one, the first inequality is fulfilled, by A2. For r_H sufficiently close to zero, neither of the inequalities are fulfilled.

(b) In the degenerate case when $r_H = r_M = 1$, an equilibrium exists provided the beliefs of firm 2 off the equilibrium path are such that f_2 will interview x_1 or make her an offer without interviewing after observing an offer. The ex-ante beliefs and beliefs fulfilling the Intuitive Criterion are examples of such beliefs.

From Lemma 3, it follows that firm 1 will never interview or make an offer to applicant 2. ■

Proof of Proposition 2

(i) Follows from Lemma 3.

(ii) First, note that unemployment trivially occurs when $F < X$. We therefore focus on the situation where $F = X$. Consider a sequence of at least three firms (for the case of two firms and two applicants the statement follows by Proposition 1 above). Define a local maximizer to be a firm that has a higher productivity than both the firm it gives an applicant to in period 2 and the firm that it receives an applicant from in period 2 – i.e. if we arrange firms in a circle such that the applicant matched with firm k in period 1 (whose productivity we denote as x_k) is matched with firm $k - 1$ in period 2, firm i is a local maximizer if and only if $f_{i-1} < f_i > f_{i+1}$. It is obvious that at least one local maximizer must exist for any sequence of firms. Let x_i and x_{i+1} be the productivity of firm i 's first and second-period applicants respectively. By Lemma 2, firm i will interview an applicant of productivity x_{i+1} (or make her an offer without interviewing) if $x_i = L$ or M . If, in addition, $x_{i+1} = M$ or H (this condition is not necessary if firm i

makes an offer without interviewing) it will hire her. By Lemma 3, firm $i-1$ will neither interview nor make any offer to applicant i . Hence, an applicant i of type M will be unemployed if $x_{i+1} = M$ or H (and also if $x_{i+1} = L$ provided that firm i makes an offer without interviewing). ■

Proof of Proposition 5

(i) Since the type of the applicant in period 2 is uncertain and interviewing is costly then, firm 3 will always make an offer to its first-period applicant if she is of type H . By assumption A2, firm 3 will either interview its second-period applicant or make her an offer without interviewing if its first-period applicant is of type M or L .

(ii) Firm 1 will not interview its second-period applicant or make her any offer without interviewing since it will never be able to hire such an applicant of type H and therefore the probability of obtaining an applicant of type M is less than or equal to $p_M / (p_M + p_L)$. To see this, note that with probability 1/2 it receives an applicant from firm 3 that (by part (i) of the proposition) always hires an applicant of type H and only passes on a first-period applicant of type M if it interviews an applicant of type M or H in period 2 (or makes the second-period applicant an offer without interviewing). With probability 1/2 it receives an applicant from firm 2. By A0, firm 2 will never make an offer without interviewing in the second period if its first-period applicant is of type H . Whether firm 2 interviews in period 2 depends on the parameters, but should it interview, by (i), it will never be able to hire its second-period applicant if she is of type H and was received from firm 3. This implies that firm 1 will never be able to hire its second-period applicant if she is of type H and was received from firm 2.²⁵ ■

Proof of Proposition 6

Step 8. Firms will only interview (make offers without interviewing to) applicants from the unmatched and misreporting pools if the expected payoff gain is greater than the cost of interviewing (the outside option).

Step 7. A firm will hire the applicant it is matched with if the (expected) payoff is at least as high as the expected payoff from hiring someone from

²⁵This depends on how offers are made at the end of the second period. It is true both if we assume that firms can make a second offer in period 2 if their first offer is rejected and if firms may wait until the resolution of first-period offers to make their second-period offers. Notice that we have not needed to specify how offers are made in period two for our other results.

the pools in step 8.

Step 4. Suppose first that all firms believe applicants report truthfully. Let m be the number of applicants reporting a type of at least M and rank firms in order of productivity such that firm F is the most productive and firm 1 the least productive. It is strictly better for firm F to report the type of the applicant it is matched with since by reporting truthfully the firm obtains the applicant with probability one if she is of type M or H (and throws her out if she, off the equilibrium path, is of type L). By misrepresenting, the firm will either remain unmatched or be matched with an applicant of lower or equal productivity, either in step 6 or in step 8. Deducing the decision of firm F , firm $F - 1$ knows that if it is matched with an applicant of type H (respectively, M), then by announcing truthfully, it will be matched with the H (respectively, M) type with probability one. By misrepresenting the type of the applicant, the firm obtains a lower or equal surplus with probability one. Continuing in this fashion, we see that unless $X = m = F$ all firms have strict incentives to report truthfully. In case $X = m = F$, then firm 1 is indifferent between reporting truthfully or not since it can always hire the same applicant from the misreporting pool by making an offer without interviewing.

Step 1. Under the beliefs that all other applicants and all firms matched with an applicant in step 3 report truthfully, an applicant of type L is indifferent between reporting or misreporting. By reporting truthfully, she will be placed in the pool of unmatched applicants in step 2. By misreporting, she will either be placed in the pool of misreporting applicants in step 5 or – if $m > F$ and she is not matched with any firm in step 3 – in the unmatched pool in step 3. No applicant of type L will be hired if we assume that the beliefs off the equilibrium path about the applicants in the misreporting pool are such that no unmatched firm, by A0, would make an offer to any member of this pool without interviewing.

Maintaining the beliefs that all other applicants and all firms matched with an applicant in step 3 report truthfully, applicants of type M have strict incentives to report truthfully:

- a) Conditional on the event that $\hat{m} < F$ other applicants report a type of at least M , reporting truthfully implies being hired by any firm $i \geq F - \hat{m}$ with positive probability and remaining unemployed with zero probability. Falsely reporting type H or L instead implies that the applicant is placed in the misreporting pool and that she can be hired only by firms $i \leq F - \hat{m}$ (assuming the applicant is matched with such a firm in step 8 and the beliefs of this firm are such that it would actually interview someone from this pool).
- b) Conditional on $\hat{m} \geq F$ other applicants reporting a type of at least

M , truthfully reporting M implies being hired by any firm with positive probability or being placed in the unmatched pool with a probability $p > 0$. Falsely reporting H implies being placed in the unmatched pool in step 3 with a probability $q \in (0, p)$, and in the misreporting pool in step 5 with probability $1 - q$. In the latter event, the only firm remaining unmatched after step 6 – firm 1 – will be assigned an applicant from the non-empty unmatched pool in step 8. Falsely reporting type L in the event that $\hat{m} \geq F$ also does not pay off implies since the applicant is then placed in the unmatched pool in step 2 and remains unemployed with probability one.

The proof for applicants of type H is analogous to the case of applicants of type M except for the fact that the probability of being placed in the unmatched pool in step 3 is equal to one after falsely reporting M when there are $\hat{h} \geq F$ other applicants reporting H . ■

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