

# Simultaneous Search and Adverse Selection\*

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February 7, 2024

## Abstract

We study the effect of diminishing search frictions in markets with adverse selection by presenting a model in which agents with private information can simultaneously contact multiple trading partners. We highlight a new trade-off: facilitating contacts reduces coordination frictions but also the ability to screen agents' types. We find that, when agents can contact sufficiently many trading partners, fully separating equilibria obtain only if adverse selection is sufficiently severe. When this condition fails, equilibria feature partial pooling and multiple equilibria co-exist. In the limit, as the number of contacts becomes large, some of the equilibria converge to the competitive outcomes of [Akerlof \(1970\)](#), including Pareto-dominated ones; other pooling equilibria continue to feature frictional trade in the limit, where entry is inefficiently high. Our findings provide a basis to assess the effects of recent technological innovations that have made meetings easier.

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\*We thank the editor and three referees for their valuable feedback. We further thank Axel Anderson, Antonio Cabrales, Gabriel Carroll, Briana Chang, Manolis Galenianos, Belen Jerez, Philipp Kircher, Stephan Lauermann, Benjamin Lester, Ilse Lindenlaub, Thomas Mariotti, Guido Menzio, Giuseppe Moscarini, Pierre-Olivier Weill, and various seminar and conference participants for helpful comments. Sarah Auster gratefully acknowledges funding from the German Research Foundation (DFG) through Germany's Excellence Strategy—EXC 2126/1—390838866 and CRC TR 224 (Project B02). Ronald Wolthoff gratefully acknowledges financial support from the Social Sciences and Humanities Research Council.

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# 1 Introduction

In this paper, we study an environment with two key ingredients, adverse selection and search frictions. Real-life markets that feature these ingredients are abundant and include labor markets, OTC markets, as well as insurance markets. In recent years, many of these markets have seen technological innovations giving rise to online platforms that made it easier for market participants to meet, thus lowering search frictions.<sup>1</sup> A natural question is how such innovations affect the strategies of traders and the resulting prices at which transactions occur and hence the properties of allocations obtained in those markets. An understanding of the welfare effects of lowering meeting barriers is important, also to guide possible regulatory interventions regarding the organization of trades in markets.

Our paper aims to provide a theoretical framework that allows us to investigate the question of how facilitating contacts affects market outcomes in the presence of adverse selection. The main innovation is to model lowering search frictions by letting agents contact multiple potential trading partners *simultaneously* into an otherwise standard framework of directed search. We demonstrate that this, in the presence of adverse selection, gives rise to a new trade-off: facilitating contacts between market participants not only means search frictions are smaller but also affects the possibility of using the liquidity properties of different markets to screen traders with private information. We show that the latter effect has significant implications for the properties of market outcomes. In contrast to the case where agents can only contact one trading partner, equilibria in our setting may exhibit partial pooling where agents of different types trade at the same price. A striking result we obtain is that some of these equilibria feature inefficient entry, even in the limit when agents can contact infinitely many other market participants. Hence, frictional trade may persist in the limit where the exogenous search friction vanishes.

Our analysis is cast in an environment as in [Akerlof \(1970\)](#), where sellers own an indivisible object and are privately informed about its quality, which can be either low or high. For expositional purposes, we adopt a labor market terminology throughout the paper: buyers are firms and sellers are workers who have private information about their productivity and can accept at most one job.<sup>2</sup> However, other applications are relevant as well; for instance,

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<sup>1</sup>As discussed by [Fermanian et al. \(2016\)](#) and [Riggs et al. \(2020\)](#), recent technological innovations (e.g., electrification) and regulatory changes (e.g., the Dodd-Frank Act) had a very significant impact on the way many securities are traded in financial markets. These innovations, together with measures aiming to increase transparency in trades, generated a substantial increase in contacts among market participants in OTC markets, where corporate bonds and derivatives like swaps are mostly traded. In the new platforms that emerged, customers can contact multiple dealers at the same time, both to have the quotes set by various dealers streamed to them (RFS) and to send a contemporaneous request for quote (RFQ) to a selected subset of dealers for a specific transaction.

<sup>2</sup>While application data is scarce, the available evidence indicates that the number of applications sent

we can reinterpret sellers as asset owners, privately informed about the asset’s future value, or producers with private information about the quality of their products.

The market works as follows. First, firms choose which wage to post, workers then send applications to  $N \geq 1$  firms, and, finally, firms make offers. A worker’s strategy thus specifies an *application portfolio*, trading off higher wages against the lower associated probabilities of getting a job offer. The matching between firms and workers is complicated by the fact that workers may receive multiple offers and can choose which one to accept. Hence, a firm’s offer may be rejected. We assume that, when this happens, the firm can keep making new offers until an applicant accepts or the firm exhausts its applicant pool, as in Kircher (2009).

We now describe our results in more detail. The most novel and striking properties of equilibria obtain when adverse selection is mild, i.e., the high types’ outside option is smaller than the net productivity of low types. In this case, when workers can send sufficiently many applications, multiple equilibria exist, all of which feature low and high types sending a subset of their applications to the same firms. Hence, in equilibrium, there is at least one submarket where the two types of workers pool their applications, so full separation cannot be sustained. This result is in clear contrast with the properties of models à la Guerrieri et al. (2010) where meetings are bilateral and the unique equilibrium is always separating.

More specifically, we show that an equilibrium exists where low and high types send a subset of their applications to a *single* pooling market and characterize its properties. For the low-type workers, the wage in the pooling market is the highest to which they apply, while for the high types, it is the lowest. Hence, low types applying in the pooling market are hoping for a ‘lucky punch,’ whereas high types view jobs offered in this market as a fallback option in case their preferred applications fail to generate offers. With multiple applications, the high-type workers’ opportunity cost of sending an application to a low wage is relatively small, and the same is true for low-type workers applying to a high wage.

As the number of applications becomes large—that is, as exogenous search frictions vanish—we prove that the probability that workers are hired in the pooling market converges to one. There are, however, too many firms entering the market, so their hiring probability is bounded away from one in the limit. Since firms need to be compensated for their entry cost in equilibrium, workers pay for the excessive entry in the form of a wage below their

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by workers has increased in recent decades (see e.g. Martinelli and Menzio, 2020), likely facilitated by the increased use of online job search since the beginning of this century, as documented by e.g. Faberman and Kudlyak (2016). Further, as discussed by Wolthoff (2018), various pieces of evidence highlight the importance of simultaneous search. First, data from online job boards shows that workers tend to send multiple applications within even the shortest time span (a week or even a day). Second, surveys among employers indicate that the most common reason for a worker to reject a job offer is the simultaneous arrival of a more attractive offer. Informational asymmetries are also a natural feature of employment relationships, especially at the onset, even though they tend to be mitigated over time with on-the-job learning.

average net productivity. Equilibrium trading is thus frictional, even in the limit, as the number of applications workers can send gets arbitrarily large.

When, instead, adverse selection is severe, there is always an equilibrium featuring complete market segmentation, no matter how many applications workers can send. In such an equilibrium, workers of different types apply to different firms. To sustain sorting, the equilibrium probability of being hired in one of the high-type markets must be sufficiently low so as to ensure incentive compatibility for low types. The larger the number of applications low types have at their disposal, the tighter this constraint becomes. In the limit, as the number of applications low types can send becomes large, the equilibrium probability of high-type workers being hired converges to zero. This property is notable, as it holds despite high types sending an infinite number of applications. The result illustrates another interesting implication of multiple applications: when adverse selection is severe, screening based on market liquidity may still occur but requires a much bigger (extreme in the limit) distortion of the trading probability.

We relate the limit results to the equilibrium outcomes in a perfectly competitive market à la [Akerlof \(1970\)](#). In our setting, a separating equilibrium exists for any number of applications workers can send if and only if the corresponding Akerlof economy has an equilibrium where only low-productivity workers are hired. Moreover, since high types are driven out of the market as  $N$  grows, the Akerlof equilibrium is the limit point of the separating search equilibria as  $N \rightarrow \infty$ . The other potential Akerlof equilibrium in a two-type economy is a pooling equilibrium where both types of workers are hired at a wage equal to their average productivity. For the case of mild adverse selection, the excessive entry result shows that there is a sequence of search equilibria such that, in the limit where  $N \rightarrow \infty$ , both types of workers are hired in the pooling market with probability one. The wage in that market is, however, strictly below the average productivity in order to compensate firms for the risk of remaining unmatched. We also show that we can find an alternative sequence of equilibria, featuring two pooling markets rather than one, such that the equilibrium allocation of this sequence converges to the pooling equilibrium of [Akerlof \(1970\)](#). Hence, in our search theoretic environment, the convergence to the set of equilibria obtained in Walrasian markets à la [Akerlof \(1970\)](#) is *possible but not necessary*, and multiplicity persists in the limit as the search friction vanishes.

We then show that, in contrast to the case of symmetric information, the welfare implications of increasing the number of applications under adverse selection are ambiguous. The reason is that increasing the workers' application capacity not only relaxes search frictions but also affects the set of allocations that are incentive-compatible. While low-productivity workers always gain, high-productivity workers may gain or lose when the capacity to apply

to multiple firms increases across the market. Focusing on the case where entry costs are small, we show that starting from the single-application benchmark, high-productivity workers lose from an additional application whenever adverse selection is severe or the fraction of low-productivity workers in the market is sufficiently large. Surprisingly, in the latter case, the loss occurs even when the additional application leads to partial pooling in equilibrium. Moving from a separating equilibrium when workers send one application to a partial pooling equilibrium when workers send two reduces the average wage at which high types are hired. Since the average productivity in the pooling market is low, this more than offsets the benefit of the associated increase in their trading probability. As a consequence, it can be beneficial for a planner to restrict innovations that facilitate meetings among market participants.

The approach pursued in this paper differs from the one followed in most of the search literature, which restricts attention to bilateral meetings, either in a static environment or in (the steady state of) a dynamic environment. In these settings, a reduction in search frictions has been modeled as an increase in matching efficiency, captured either by the probability or the rate at which trading partners meet. Reducing search frictions in this way, however, has generally no qualitative impact on the nature of equilibrium outcomes. Indeed, for the case of directed search with adverse selection, [Guerrieri et al. \(2010\)](#) and [Chang \(2018\)](#) found that the key properties of equilibrium outcomes remain unchanged as the matching technology becomes efficient or sequential meetings become arbitrarily frequent: the limit equilibrium features perfectly segmented markets in which the lowest type trades with probability one, while higher types trade with a smaller but still positive probability. Our analysis shows that modeling declining search frictions as an increase in the number of simultaneous meetings modifies the properties of equilibria in important ways and allows to get the competitive market outcome as a limit equilibrium allocation when search frictions vanish.

In a similar vein, [Diamond \(1971\)](#) demonstrated for the case of sequential random search à la [McCall \(1970\)](#) that when prices are endogenized, we obtain the surprising prediction that the equilibrium always features monopoly pricing and does not converge to the competitive outcome, even as search frictions become arbitrarily small. [Butters \(1977\)](#), [Varian \(1980\)](#) and [Burdett and Judd \(1983\)](#) showed that allowing buyers to meet multiple sellers simultaneously offers a resolution to the Diamond paradox. Specifically, they found that competitive pricing is obtained in the limit as the probability of meeting multiple trading partners converges to one. Part of our contribution is to provide analogous insights for the case of directed search with adverse selection.<sup>3</sup>

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<sup>3</sup>We thank a referee for this valuable insight.

**Related literature.** Our paper contributes to various strands of literature. The two most related strands, as already discussed, concern models of simultaneous search and the work on adverse selection in directed search environments. The first strand includes [Chade and Smith \(2006\)](#), [Albrecht et al. \(2006\)](#), [Galenianos and Kircher \(2009\)](#), [Wolthoff \(2018\)](#) and [Albrecht et al. \(2020\)](#). Our model builds in particular on [Kircher \(2009\)](#), with respect to which we innovate by allowing for searcher heterogeneity and introducing asymmetric information. The second strand includes [Gale \(1996\)](#), [Inderst and Müller \(2002\)](#), [Guerrieri et al. \(2010\)](#) and [Chang \(2018\)](#), relative to which we innovate by allowing for simultaneous search.

The consequences of multiple applications for the properties of equilibrium outcomes with search frictions have interesting analogies to those of non-exclusivity in contracting without such frictions. The latter also limits, though in different ways, the ability of firms to screen workers. Our environment features exclusivity in contracting, as each worker can accept only one offer, but not in applications, as a worker can apply to many firms and the set of all his applications is not observable by firms. When firms compete with non-exclusive contract offers, [Attar et al. \(2011\)](#) find that pooling obtains in equilibrium under the same condition as in [Akerlof \(1970\)](#), otherwise high quality sellers are excluded from trade and the equilibrium is unique. Our analysis differs in various respects. Unlike in [Attar et al. \(2011\)](#), firms in our model face a capacity constraint in their hiring, which limits their market power. As a result, the forces breaking separating equilibria and sustaining pooling trades in the two setups are rather different. Furthermore, multiplicity of equilibria and inefficient entry are distinctive phenomena of our analysis. Finally, our setup also allows to investigate the properties of equilibrium outcomes where firms can only submit a finite number  $N$  of applications, so non-exclusivity at the application stage is only partial, gaining interesting insights on the effects of varying  $N$ .

To conclude, a number of papers on frictional markets with adverse selection share important analogies with our work in some aspects, but ultimately focus on rather different questions from ours. [Lester et al. \(2019\)](#) consider a market where sellers may meet either one or two buyers, but meetings are random. In their environment, the fact that sellers may meet multiple buyers affects the price at which they trade, but not their probability of trade, because buyers have no capacity constraints. The main focus of their work is then on the effects of multiple meetings on buyers' market power. [Kurlat \(2016\)](#) and [Board et al. \(2020\)](#) also consider a labor market in which heterogeneous workers contact multiple firms, but the main emphasis is on the matching that arises when firms are heterogeneous in their ability to detect workers' types. [Lauermann and Wolinsky \(2016\)](#) and [Kaya and Kim \(2018\)](#) consider the effect of vanishing search frictions, but in a sequential random search environment with adverse selection and private noisy signals about the type of the informed party. [Kim and](#)

Pease (2017) also study sequential search with adverse selection. In contrast to the previous papers, they allow the privately informed party to choose the search intensity and show that lower search costs may lead to worse equilibrium outcomes for the informed party. The result relies on the observability of the informed party’s trading history, an important difference from our analysis in Online Appendix D.

The paper is organized as follows. Section 2 presents the framework. Some preliminary properties are derived in Section 3. Section 4 characterizes search equilibria, first for the case of severe adverse selection, then for the case of mild adverse selection. Section 5 discusses the welfare effects of increasing workers’ application capacities and potential policy implications. Section 6 concludes. Proofs and additional results are relegated to the (Online) Appendix.

## 2 Environment

**Agents.** We consider a static labor market populated by a continuum of size one of workers and a large continuum of firms. Both types of agents are risk-neutral. Workers supply and firms demand one unit of indivisible labor. All firms are identical, but workers differ in their productivity, defining their type, which is private information. In particular, a fraction  $\sigma$  of workers have low productivity, while the remaining ones are of high productivity. We will index types by  $i \in \{L, H\}$ .

**Market interaction.** The market interaction between workers and firms proceeds in multiple subsequent stages. In the first stage, firms decide whether to become active or not. Active firms incur an entry cost  $k > 0$  and subsequently post and commit to a wage  $p$  that they will pay if they hire. The support of the distribution of posted wages is denoted by  $\mathcal{F}$ .

After observing all posted wages, in the second stage, each worker sends  $N \in \{1, 2, \dots\}$  job applications to firms.<sup>4</sup> As standard in the directed search literature (see e.g. Shimer, 2005) and motivated by the idea that coordination among a continuum of agents in decentralized markets is unrealistic, we restrict workers to symmetric and anonymous strategies, which creates the search frictions we study. That is, for each application a worker selects a wage and then applies at random to one of the firms posting such wage. A worker’s application portfolio is thus a list of  $N$  wages. As we will show, whenever a worker has the opportunity to send an additional application, that application will be sent to a (weakly) higher wage than the previous ones. It is then convenient to order the applications sent in a weakly increasing order, so a portfolio is described by  $(p_1, \dots, p_N) \in \mathcal{F}^N$ , with  $p_1 \leq \dots \leq p_N$ . Although the worker sends all  $N$  applications simultaneously, it will often be useful to refer

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<sup>4</sup>We will generally focus on  $N \geq 2$ , but include  $N = 1$  for completeness and comparison with the literature.

to  $p_n$ , i.e. the  $n$ -th lowest application, as the worker's  $n$ -th application.

After all the applications are sent, matches are formed. Following Kircher (2009), we assume that the matching of workers and firms on the network induced by the workers' applications is stable, i.e., no firm remains unmatched when one of its applicants is hired at a lower wage. One way to implement a stable outcome is via a sequential procedure in the spirit of deferred acceptance (Gale and Shapley, 1962). First, each firm with applicants randomly selects one of them and makes a job offer. Every worker then keeps the best job offer he received under consideration (without loss of generality, in the event of ties, we take this to be the offer with the highest index) and rejects all worse job offers. Next, firms whose job offers are rejected select a different applicant (as long as they still have one) and make a new job offer. After this, the process repeats until there are no more rejections or no firm can make any additional offers. At that point, workers accept the job offer under consideration.<sup>5</sup>

Finally, after matches are formed, production takes place and payoffs are realized. A match between a firm and a worker of type  $i$  results in an output  $v_i$ , where  $v_H \geq v_L$ . The firm's payoff from the match is the difference between this output and the wage  $p$  it pays. In contrast, the worker's payoff from the match is the difference between this wage and his outside option (or disutility from effort)  $c_i$ . This also depends on the worker's type, with  $c_H > c_L$ , motivated by the idea that high-productivity workers have better opportunities in outside markets or self-employment. Unmatched workers and inactive firms receive a zero payoff. We assume the productivity of each type of worker, net of the firm's entry cost, exceeds the worker's outside option:  $v_i - k > c_i$ ,  $i = H, L$ . Hence, there are positive gains from trade with each worker.

**Queues.** Consider a (*sub*)market  $p \in \mathcal{F}$ , defined as the collection of all the firms posting this wage and of all the applications they receive. From the firms' perspective, each application has two unobservable but payoff-relevant characteristics: i) its position  $n \in \{1, \dots, N\}$  in the sender's application portfolio, which affects the firms' matching probability, and ii) the type  $i \in \{L, H\}$  of its sender, which affects the firms' payoff conditional on a match.

Define the *queue length*  $\lambda_{n,i}(p) \in \mathbb{R}_+$  as the endogenous ratio of the number of applications with characteristics  $(n, i)$  to the number of firms in submarket  $p$ . As well-known in the literature, the number of applications with characteristics  $(n, i)$  at a firm posting a wage  $p$  follows a Poisson distribution with a mean equal to this queue length, independently of the number of applications with other characteristics.<sup>6</sup> Some of these applications however

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<sup>5</sup>The same outcome can also be motivated as the result of a process in which the market clears from the top, i.e., firms posting the highest wages make job offers first, followed by firms posting the next highest wages, etc.

<sup>6</sup>See Lester et al. (2015) and Cai et al. (2017) for a discussion of this property, which they call *invariance*.



will end up being not relevant for the firm as the worker will turn down a job offer due to the receipt of better offers from other firms. Denote by  $\xi_{n,i}(p) \in [0, 1]$  the endogenous probability that an applicant with characteristics  $(n, i)$  accepts a job offer at  $p$ . The number of *effective* applicants with characteristics  $(n, i)$  at a firm posting wage  $p$  follows then a Poisson distribution with mean (or *effective queue length*)  $\mu_{n,i}(p) = \xi_{n,i}(p)\lambda_{n,i}(p) \in \mathbb{R}_+$ .

**Payoffs.** The probability that a firm posting a wage  $p$  hires a worker depends on the total effective queue length in that market, obtained by aggregating the queues across all applicants' characteristics

$$\mu(p) \equiv \sum_n \sum_i \mu_{n,i}(p), \quad (1)$$

and is given by the probability the firm has at least one effective applicant,  $\eta(\mu(p)) \equiv 1 - e^{-\mu(p)}$ . The hire will then turn out to be an  $L$ -type worker with probability equal to the effective fraction of  $L$ -type workers

$$\gamma(p) \equiv \sum_n \mu_{n,L}(p) / \mu(p) \quad (2)$$

and an  $H$ -type worker with complementary probability. The expected profit  $\pi(p)$  of a firm offering wage  $p$  is then given by the probability of hiring a worker, times his expected productivity minus  $p$ , less the entry cost:

$$\pi(p) = \eta(\mu(p)) (\gamma(p)v_L + (1 - \gamma(p))v_H - p) - k. \quad (3)$$

Active firms choose a posted wage  $p$  so as to maximize their profit  $\pi(p)$ . Free entry implies that in equilibrium these profits are zero.

The expected payoff of a worker applying to  $(p_1, \dots, p_N)$  also depends on the total effective queue length at these wages. The worker obtains a payoff  $p_n - c_i$  if two conditions are satisfied. First, the application to  $p_n$  results in a job offer, which happens with probability  $\psi(\mu(p_n)) \equiv \eta(\mu(p_n)) / \mu(p_n)$ . Second, none of the applications to higher wages  $p_{n+1}, \dots, p_N$  result in a job offer, which is the case with probability  $\prod_{j=n+1}^N (1 - \psi(\mu(p_j)))$ . The expected payoff  $u_{N,i}$  of a type  $i$  worker from the optimal choice of his  $N$  applications is then

$$u_{N,i} = \max_{(p_1, \dots, p_N) \in \mathcal{F}^N} \sum_{n=1}^N \prod_{j=n+1}^N (1 - \psi(\mu(p_j))) \psi(\mu(p_n)) (p_n - c_i).$$

As in Kircher (2009), this payoff can be rewritten in a recursive way, where

$$u_{n,i} = \max_{p \in \mathcal{F}} \psi(\mu(p)) (p - c_i) + (1 - \psi(\mu(p))) u_{n-1,i} \quad (4)$$

is the payoff of the first  $n$  applications, for all  $n \in \{1, \dots, N\}$ , and  $u_{0,i} = 0$ . Intuitively, the worker's  $n$ -th application leads to a wage offer  $p$  with probability  $\psi(\mu(p))$ ; with complementary probability, the worker does not receive such an offer, but still has the chance that one of his applications to lower wages is successful, yielding a conditional payoff equal to  $u_{n-1,i}$ . Since  $u_{n-1,i}$  is the expected payoff from sending  $n-1$  applications to wages below  $p_n$  and trading at those wages occurs with probability less than 1, it follows from the above equation that  $u_{n,i}$  is strictly increasing in  $n$ . Going forward, we will often refer to  $c_i + u_{n-1,i}$  as the worker's *effective outside option* when sending his  $n$ -th application, and to  $u_{n,i}$  as his *market utility* from sending  $n$  applications.

**Beliefs.** In order to decide whether to post a particular wage  $p$ , a firm needs to form beliefs about the applicant pool  $(\mu(p), \gamma(p))$  that it will attract. Similarly, a worker considering applying at wage  $p$  chooses on the basis of beliefs over  $\mu(p)$ . If the wage is part of the equilibrium choices of firms,  $p \in \mathcal{F}$ , these beliefs are determined by the consistency conditions with firms' and workers' strategies, as described above. In particular, worker optimization implies that the effective queue length  $\mu(p)$  must satisfy

$$u_{n,i} \geq \psi(\mu(p)) (p - c_i - u_{n-1,i}) + u_{n-1,i}, \quad (5)$$

with weak inequality for all  $(n, i)$  and with equality for at least one  $(n, i)$  if  $\mu(p) > 0$ .

If, instead, the wage is not part of the equilibrium, we follow the standard assumption in the directed search literature (see Wright et al., 2021) that these beliefs are pinned down by the *market utility condition*, which aims to capture the consequences of deviations in our continuum economy in the spirit of subgame perfection. In particular, the market utility condition extends the optimization condition (5) to all  $p$  that are not part of an equilibrium. That is, a firm posting  $p \notin \mathcal{F}$  expects an effective queue length  $\mu(p)$  implying the smallest job offer probability that is needed to induce one of the workers' types to redirect one of their applications to  $p$ , indeed in the spirit of subgame perfection. This also pins down beliefs about the market composition: at this wage, the firm expects to attract applicants of a certain type only if (5) holds with equality for that type for some  $n$ . That is, for any

$p \notin \mathcal{F}$ ,  $\gamma(p)$  satisfies

$$\begin{cases} \gamma(p) \mu(p) = 0 & \text{if (5) holds with strict inequality for } i = L \text{ and all } n \\ (1 - \gamma(p)) \mu(p) = 0 & \text{if (5) holds with strict inequality for } i = H \text{ and all } n. \end{cases} \quad (6)$$

**Equilibrium.** We can then define an equilibrium as follows.<sup>7</sup>

**Definition 1.** *An equilibrium is a set of wages  $\mathcal{F}$  posted by firms, effective queue lengths and compositions  $(\mu(p), \gamma(p))$  for all  $p$ , and market utilities  $u_{n,i}$  for all  $n$  and  $i$ , such that the following conditions are satisfied.*

1. *Worker Optimization: a worker of type  $i$  sends his  $n$ -th application to wage  $p \in \mathcal{F}$  only if (5) holds as equality;*
2. *Firm Optimization:  $\pi(p) = 0$  for any  $p \in \mathcal{F}$ , and  $\pi(p) \leq 0$  for any  $p \notin \mathcal{F}$ ;*
3. *Consistency: for any  $p \in \mathcal{F}$ ,  $\mu(p)$  and  $\gamma(p)$  are consistent with workers' and firms' strategies;*
4. *Out-of-Equilibrium Beliefs: for any  $p \notin \mathcal{F}$ ,  $\gamma(p)$  satisfies (6) and  $\mu(p)$  satisfies (5) with weak inequality for any  $(n, i)$ , and with equality for at least one  $(n, i)$  if  $\mu(p) > 0$ .*

In what follows, we shall refer to a submarket where only  $L$ -types ( $H$ -types) apply as an  $L$ -type market ( $H$ -type market).

## 3 Preliminaries

### 3.1 Indifference and Isoprofit Curves

Most of our analysis of workers' and firms' choices and hence of equilibria can be presented graphically by considering workers' indifference curves and firms' isoprofit curves. To facilitate this approach, we introduce these curves here and discuss some useful properties.

**Isoprofit curves.** As equation (3) shows, firms' profits depend not only on the price  $p$  and the effective queue length  $\mu$ , but also on the queue composition  $\gamma$ . Hence, we need to specify the value of  $\gamma$  to be able to pin down a firm's isoprofit curve as the set of all combinations of  $\mu$  and  $p$  satisfying the free entry condition. The two extremes in which the firm respectively

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<sup>7</sup>To keep the notation simple in the main text, in the definition of equilibrium, we state the consistency condition somewhat informally. We provide the full details in Online Appendix C.

attracts only low (i.e.  $\gamma = 1$ ) or high types ( $\gamma = 0$ ) will prove to be particularly useful for our analysis. The isoprofit curves in those two cases are defined as

$$\Pi_i \equiv \{(\mu, p) \in \mathbb{R}^2 : \eta(\mu)(v_i - p) = k\}, \quad (7)$$

with  $i \in \{L, H\}$ .

**Indifference curves.** The indifference curve  $I_{n,i}$  of a worker of type  $i$  sending his  $n$ -th application consists of all combinations of  $\mu$  and  $p$  that solve (5) with equality.

$$I_{n,i} \equiv \{(\mu, p) \in \mathbb{R}^2 : \psi(\mu)(p - c_i) + (1 - \psi(\mu))u_{n-1,i} = u_{n,i}\}. \quad (8)$$

Differentiating (8) we see the slope of a worker's indifference curve equals

$$\frac{d\mu}{dp} = -\frac{\psi(\mu)}{\psi'(\mu)} \frac{1}{p - c_i - u_{n-1,i}} > 0.$$

This yields some helpful properties. The slope depends on the type of the worker (only) through his effective outside option  $c_i + u_{n-1,i}$ . When this varies with  $i$ , the two types have different marginal rates of substitution between wage and matching probability for their  $n$ -th application, which creates scope for screening. For the first application, this is the case by assumption since  $u_{0,L} = u_{0,H} = 0$  and  $c_H > c_L$ . For subsequent applications  $n = 2, 3, \dots$  however, the effective outside option is endogenous. It is immediate to see from the above expression that a worker's indifference curve becomes steeper as the index  $n$  of the application increases. Intuitively, as the effective outside option of a worker increases, he is willing to tolerate a larger increase in the effective queue length to obtain a higher wage. It is also clear that, for the same index of the application, the high type has steeper indifference curves, i.e.  $c_L + u_{n-1,L} < c_H + u_{n-1,H}$  for all  $n$ . What is less obvious, however, is how  $c_L + u_{n-1,L}$  compares to  $c_H + u_{m-1,H}$  for  $n > m$ . This question will be at the center of our analysis in the following section.

## 3.2 Observable Types

It will be useful to describe first the equilibrium allocation that arises if worker types are observable to firms and hence incentive constraints are absent, as obtained by Kircher (2009).

**Equilibrium allocation.** Due to free entry, the equilibrium allocation in this case can be determined for each worker type  $i$  in isolation. It is entirely pinned down by the free entry condition and the first-order condition of the firms' choice problem, taking into account beliefs as determined by market utility. Graphically, these beliefs are represented by the

upper envelope of workers' indifference curves  $I_{n,i}$ ,  $n \in \{1, \dots, N\}$ . The effective queue lengths and wages for the  $N$  applications of each worker are then determined by the tangency points between the firms' isoprofit curve  $\Pi_i$  and this upper envelope, as illustrated in Figure 1. As shown by Kircher (2009), letting  $p_{n,i}^*$  denote the wage to which a worker of type  $i$  sends his  $n$ -th application, one can combine these conditions to recursively characterize the equilibrium effective queue length  $\mu_{n,i}^* \equiv \mu(p_{n,i}^*)$  and the associated market utility  $u_{n,i}^*$  for each application  $n$  and each type  $i = L, H$ . The procedure is as follows: set  $u_{0,i}^* = 0$  and let  $\{\mu_{n,i}^*, u_{n,i}^*\}_{i=1}^N$  be such that

$$k = (\eta(\mu_{n,i}^*) - \mu_{n,i}^* \eta'(\mu_{n,i}^*)) (v_i - c_i - u_{n-1,i}^*), \quad (9)$$

$$u_{n,i}^* = u_{n-1,i}^* + \eta'(\mu_{n,i}^*) (v_i - c_i - u_{n-1,i}^*). \quad (10)$$

Since the indifference curves become steeper as the index  $n$  of the application increases, the tangency point for this application moves up the firms' isoprofit curve to a higher wage and effective queue length.

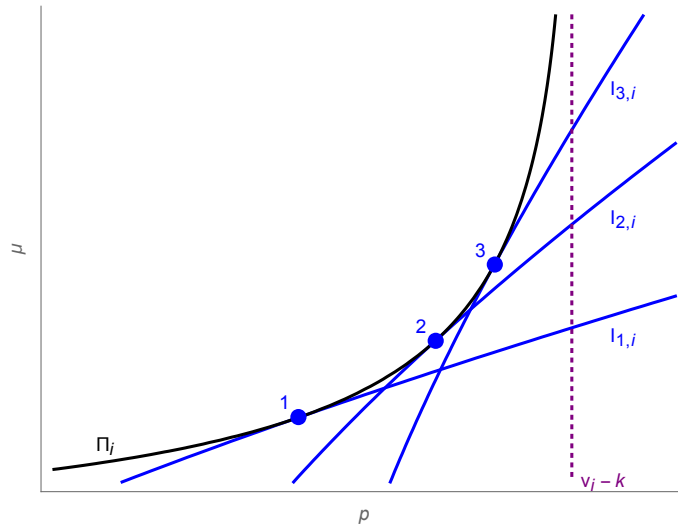


Figure 1: Equilibrium wages and effective queue lengths when the type is observable and workers send three applications.

The allocation implied by (9) and (10) will be different for workers of different types, since the firms' willingness to offer a wage  $p$  with queue length  $\mu$  depends on the worker's type  $i$ , determining the firm's payoff  $v_i$  from hiring the worker. Similarly, workers of different types exhibit different preferences over portfolios of applications because their trade-off between the wage and the probability of being hired depends on their outside option  $c_i$ . Hence, with heterogeneous, observable types, the equilibrium features a separate submarket for each type and each application (at least generically).

**Vanishing search frictions.** Kircher (2009) shows that as the number of applications  $N$  goes to infinity, the equilibrium allocation tends to the Walrasian outcome in which all firms active in the market hire a worker with probability one and every worker finds a job. To see this, notice first that the difference  $u_{N,i} - u_{N-1,i}$  converges to zero as  $N \rightarrow \infty$ , since  $u_{N,i}$  is strictly increasing in  $N$  and bounded above by the gains from trade,  $v_i - c_i - k$ . This property implies that the effective queue length  $\mu_{N,i}^*$  tends to  $\infty$ , as can be seen from (10).<sup>8</sup> Since  $\lim_{N \rightarrow \infty} \mu_{N,i}^* = \infty$ , every firm hires a worker, so the free-entry condition (9) requires that a worker's expected utility from his portfolio of applications,  $u_{N,i}^*$ , tends to  $v_i - c_i - k$  as  $N \rightarrow \infty$ . Because no firm would offer a wage greater than  $v_i - k$ , this implies that in the limit, a worker is hired at a wage  $v_i - k$  with probability one. It further means that the measure of firms posting wages that are bounded away from  $v_i - k$  (for which the effective queue length is finite) tends to 0. In other words, all entering firms hire with a probability of one in the limit. The impact of the search friction thus disappears in the limit where each worker can submit infinitely many applications, and the equilibrium allocation converges to the Walrasian outcome.

## 4 Equilibria with Adverse Selection

As seen in the previous section, allowing workers to apply simultaneously to multiple firms mitigates the search friction and, therefore, increases the trading probability of workers and firms when this friction is the only impediment to trade. We show next that in environments with adverse selection, the same result may no longer hold, as incentive constraints limit trades as well. The possibility of sending multiple applications diminishes the screening role of market liquidity since workers can hedge against the possibility of not being hired in an illiquid market by sending some of their applications to more liquid markets. Hence, in markets with adverse selection, an interesting trade-off arises: allowing workers to submit multiple applications, on the one hand, reduces the search friction but, on the other hand, restricts the possibility of screening workers. In what follows, we will analyze how this trade-off shapes the properties of equilibrium allocations.

**Incentive constraints.** When types are unobservable, the allocation described in the previous section will often not be sustainable in equilibrium. The reason is that, due to the interdependence of values,  $L$ -type workers may find it profitable to send some applications to the submarkets designed for  $H$ -type workers. This point is illustrated in Figure 2, where we display the equilibrium allocation when both types are observable. Graphically, there are two relevant isoprofit curves for the firms, one for hiring the  $H$ -type and one for hiring the

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<sup>8</sup>Since  $u_{N,i} - u_{N-1,i} \rightarrow 0$ , (10) implies that  $\eta'(\mu(p)) = e^{-\mu(p)} \rightarrow 0$  and hence  $\mu(p) \rightarrow \infty$ .

$L$ -type. The  $H$ -isoprofit curve is shifted to the right with respect to the  $L$ -isoprofit curve because for each effective queue length  $\mu$ , a firm is willing to pay a higher wage  $p$  for a worker of high productivity. In Figure 2 incentive compatibility is violated for  $L$ -type workers when they can send  $N \geq 2$  applications. They can gain, for instance, by sending their second application to the market where  $H$ -type workers send their first.

Note that the  $L$ -type incentive constraints may be binding already in the case where workers send a single application. Multiple applications, however, tighten this constraint. Indeed, if  $v_H$  is strictly greater than  $v_L$ , incentive constraints necessarily bind whenever the number of applications that workers can send is sufficiently large. To see this, recall that the equilibrium with observable types converges to the Walrasian allocation when  $N \rightarrow \infty$ . In this limit both types of workers are hired with probability one, but the expected wage for the  $H$ -type,  $v_H - k$ , is strictly greater than that for the  $L$ -type,  $v_L - k$ . As a result,  $L$ -type workers have strict incentives to send some of their applications to a market with a wage strictly above  $v_L - k$ . Hence, the allocation found in Section 3.2 does not constitute an equilibrium when workers' productivity is only privately known by them.

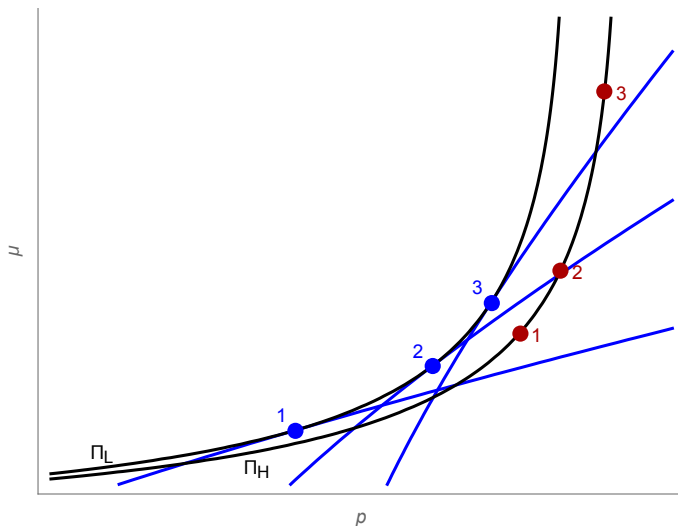


Figure 2: Equilibrium wages and effective queue lengths for the low type (blue) and the high type (red) when types are observable.

## 4.1 Severe Adverse Selection

The properties of the equilibrium allocation in our setting with multiple applications will depend on the severity of adverse selection. We first consider the case where adverse selection is severe, in the sense that the outside option of high-productivity workers is weakly greater

than the net productivity of low types, i.e.,  $c_H \geq v_L - k$ , or the *lemons condition* holds.<sup>9</sup>

Our first result shows that, as long as the lemons condition holds, the fact that workers can send multiple applications does not fundamentally change the qualitative properties of search equilibria compared to the case where they can only send a single application. To recall, when workers apply to only one firm, we know from Guerrieri et al. (2010) and others that the unique equilibrium features complete market segmentation:  $L$ -type workers apply to a different market, with a lower price and a lower queue length, than the one to which high types apply. In our setting, the lemons condition guarantees that such sorting is sustained in equilibrium regardless of the number of applications workers can send.

**Proposition 1.** *If  $c_H \geq v_L - k$ , for all  $N \geq 1$  there exists a separating equilibrium, where  $H$ -type workers apply to strictly higher wages than  $L$ -type workers.*

The construction of a separating equilibrium is as follows. The markets in which  $L$ -types apply are the same as in the equilibrium allocation of the observable type case: for all  $n = 1, \dots, N$ ,  $(\mu_{n,L}, p_{n,L}) = (\mu_{n,L}^*, p_{n,L}^*)$ . The presence of  $H$ -type workers thus has no effect on  $L$ -type choices. In contrast, the wages and effective queue lengths of the  $H$ -type markets are generally affected by the incentive constraints of  $L$ -type workers. We construct these markets sequentially. If the unconstrained solution for the  $H$ -types' first application,  $(\mu_{1,H}^*, p_{1,H}^*)$ , satisfies the  $L$ -type incentive constraints, then the effective queue lengths and wages in all the  $H$ -type markets are determined as in the observable type case, i.e., for all  $n = 1, \dots, N$ ,  $(\mu_{n,H}, p_{n,H}) = (\mu_{n,H}^*, p_{n,H}^*)$ . If, on the other hand,  $(\mu_{1,H}^*, p_{1,H}^*)$  violates the  $L$ -type incentive constraints,  $(\mu_{1,H}, p_{1,H})$  is given by the smallest effective queue length and wage on the isoprofit curve  $\Pi_H$  such that incentive compatibility holds. In this case, to find the  $H$ -type's second application, we consider the tangency point between  $\Pi_H$  and the  $H$ -type worker's second indifference curve, i.e., the one corresponding to the effective outside option  $c_H + u_{1,H}$ . If this point satisfies  $\mu_{2,H} > \mu_{1,H}$ , incentive compatibility does not bind for the second application and the same is true for the remaining applications. Otherwise, incentive compatibility also binds for the second application of the  $H$ -type workers, in which case they send their first and second applications to the same market. We repeat this procedure for the next applications until we reach the last application  $n = N$ .

By construction, the candidate separating equilibrium satisfies the incentive constraints of  $L$ -types. Hence, it constitutes an equilibrium as long as  $H$ -type workers have no incentives to send some of their applications to  $L$ -type markets. Since  $p_{n,L}^* < v_L - k \leq c_H$  for all  $n \geq 1$ , wages in the  $L$ -type remain strictly below the high types' outside option, which means that those incentive constraints are always satisfied.

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<sup>9</sup>The lemons condition, as e.g. in Daley and Green (2012), is usually stated as  $c_H > v_L$ , for the case of no entry costs.



Note that, in equilibrium,  $H$ -type workers may send multiple applications to the same submarket, as illustrated for the case of two applications in Figure 3. This feature does not arise in the observable type case, as it is driven by the binding incentive constraints.

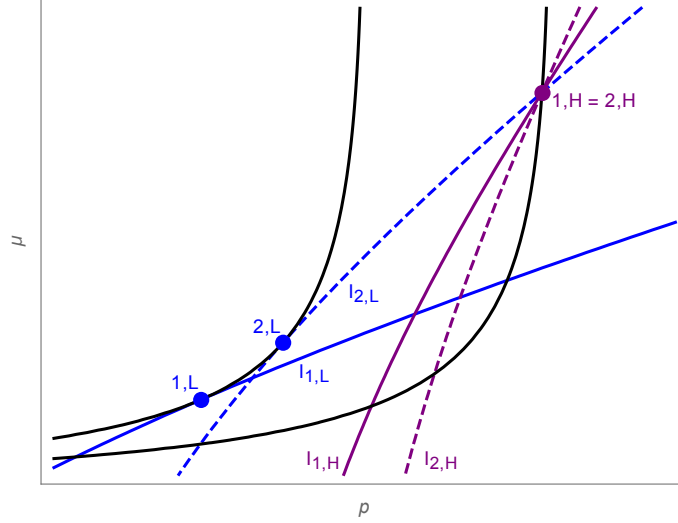


Figure 3: Equilibrium wages and effective queue lengths when workers send two applications, and incentive constraints bind for both applications of the high type.

**Vanishing search frictions.** As the number of applications low-productivity workers can send grows, their incentive constraints become increasingly tight, thereby pushing up the queue length in the markets where high-productivity workers search. Intuitively, when workers have a large number of applications at their disposal, the opportunity cost of diverting one of these applications to an  $H$ -type market becomes very small. Incentive compatibility then requires that, as  $N \rightarrow \infty$ , the queue length in the markets to which  $H$ -types apply tends to  $\infty$ . Thus, as the number of applications grows,  $H$ -type workers face increasingly congested markets. The following proposition shows that, in the limit, the increase in congestion outweighs the larger number of applications for these workers, so that  $H$ -type workers are eventually driven out of the market.

**Proposition 2.** *Assume  $c_H \geq v_L - k$ . As  $N \rightarrow \infty$ , the probability that an  $H$ -type worker is hired in a separating equilibrium tends to zero. The market utilities for  $L$ - and  $H$ -type workers take the following limits:*

$$\begin{aligned} \lim_{N \rightarrow +\infty} u_{N,L} &= v_L - c_L - k, \\ \lim_{N \rightarrow +\infty} u_{N,H} &= 0. \end{aligned}$$

To prove the result, we consider a candidate separating equilibrium where  $H$ -type workers

are hired with a strictly positive probability and then construct a profitable deviation for low types. If low types follow the equilibrium strategy and send all their applications to the respective  $L$ -type markets, their probability of being hired tends to one and their wage to  $v_L - k$ . Suppose instead an  $L$ -type worker sends half of his applications to the first  $N/2$   $L$ -type markets and the remaining applications to the  $H$ -type market with the lowest effective queue length. Since  $N$  is arbitrarily large, the probability of being hired in one of the  $L$ -type markets is still arbitrarily close to one and the wage is arbitrarily close to  $v_L - k$ . We then show that sending half of the applications to the  $H$ -type market allows the  $L$ -type worker to be hired in that market with strictly positive probability. Since the wage in the  $H$ -type market is greater than  $c_H$ , which in turn is greater than  $v_L - k$ , this portfolio of applications generates a strictly higher expected wage and thus constitutes a profitable deviation.

## 4.2 Mild Adverse Selection

We now turn our attention to the most interesting case in our setup, where the lemons condition fails:  $c_H < v_L - k$ . Under this condition, we will show that allowing workers to send more than one application has two novel, important implications: (i) *equilibria with perfect market segmentation exist only if  $N$  is sufficiently small* and (ii) *pooling markets may be active in equilibrium*. Also, when (ii) occurs, there are typically multiple ways in which workers of different types can pool some of their applications, so the equilibrium is no longer unique.

We start by presenting the main result. The following proposition shows that there exists a threshold for the total number of applications  $N$  such that a fully separating allocation constitutes an equilibrium only when  $N$  is below that threshold, while a new type of equilibrium with a pooling market arises when  $N$  is above the threshold. The threshold is identified by the number of applications at which the payoff of the  $L$ -types in the equilibrium of the benchmark case with observable types becomes larger than the  $H$ -type's outside option. Formally:

$$l \equiv \min\{n \in \mathbb{N} : u_{n,L}^* + c_L > c_H\}. \quad (11)$$

To state the result, we will require that  $v_H$  is sufficiently distinct from  $v_L$  so that we are sufficiently far from the private value case. This will imply, as we explain in what follows, that in equilibrium  $H$ -types apply to weakly higher wages than  $L$ -types. In the proof of Proposition 3 we provide an explicit lower bound for  $v_H$ .

**Proposition 3.** *Assume  $c_H < v_L - k$ .*

1. *A separating equilibrium where  $L$ - and  $H$ -types send their applications to distinct sub-markets exists if and only if  $N \leq l$ .*

2. If  $N > l$ , there exists an equilibrium with a single pooling market. In this equilibrium,  $L$ -types send their first  $l$  applications to separate submarkets and the remaining applications to the pooling market. In contrast,  $H$ -types send their last  $l$  applications to separate submarkets and their remaining applications to the pooling market.

*Separating equilibrium.* We first look at the possible existence of a fully separating equilibrium. As we prove in the Appendix, any such equilibrium must follow the same construction as the one in Section 4.1.<sup>10</sup> This construction implies, as we already mentioned, that the incentive constraints of  $L$ -type workers are always satisfied. However, since  $\lim_{n \rightarrow \infty} p_{n,L}^* = v_L - k$  and  $c_H < v_L - k$ , some wages in the  $L$ -type markets are now acceptable to  $H$ -type workers when  $N$  is sufficiently large. The incentive constraints of the  $H$ -type workers must therefore also be examined. A separating equilibrium exists as long as workers of type  $H$  do not want to send any of their applications to one of the  $L$ -type markets.

A necessary and sufficient condition for this to be true is that the  $L$ -type workers' effective outside option associated with their last application,  $c_L + u_{N-1,L}$ , remains below the  $H$ -type workers' outside option,  $c_H$ , or equivalently, that  $N \leq l$ . When this happens, all indifference curves of  $L$ -type workers are flatter than those of  $H$ -type workers. This sorting condition is precisely the feature that allows firms to screen high-productivity workers on the basis of their greater propensity to accept longer queue lengths for higher wages. If instead  $N$  is strictly greater than  $l$ , then the sorting condition is reversed for the last application(s) of the  $L$ -type workers, and perfect market segmentation cannot be sustained in equilibrium.

*Equilibrium with partial pooling.* When the separating equilibrium fails to exist ( $N > l$ ), Proposition 3 says that there is a partial pooling equilibrium where  $L$ -type workers and  $H$ -type workers send a subset of their applications to a single pooling market.

Let us first recall why a pooling market cannot be sustained in equilibrium when  $N = 1$ . Suppose an equilibrium existed with a pooling market  $(\bar{\mu}, \bar{p})$  attracting both types, as illustrated by the green point in Figure 4. Since firms attract both types, the isoprofit curve associated with zero profits lies between  $\Pi_L$  and  $\Pi_H$ , as illustrated by the green curve in the figure. Due to the higher outside option, the indifference curve of the  $H$ -type passing through  $(\bar{\mu}, \bar{p})$  is steeper than that of the  $L$ -type. This difference in marginal rates of substitution implies that high types are willing to tolerate longer effective queue lengths than low types in any market with a wage higher than  $\bar{p}$ . In other words, an  $H$ -type worker has more to gain by applying to a wage above  $\bar{p}$  than an  $L$ -type worker. If a firm deviates and increases the wage above  $\bar{p}$ , it thus expects to attract only  $H$ -type workers. Hence, a marginal increase in the

<sup>10</sup>The property that  $H$ -type workers apply to strictly higher wages than  $L$ -type workers—even when the lemons condition fails—is again guaranteed by the condition  $v_H \geq \bar{v}_H$ .

wage and the associated queue length leads to a discrete improvement in the composition of the applicant pool and thus constitutes a profitable deviation, effectively a cream-skimming deviation.

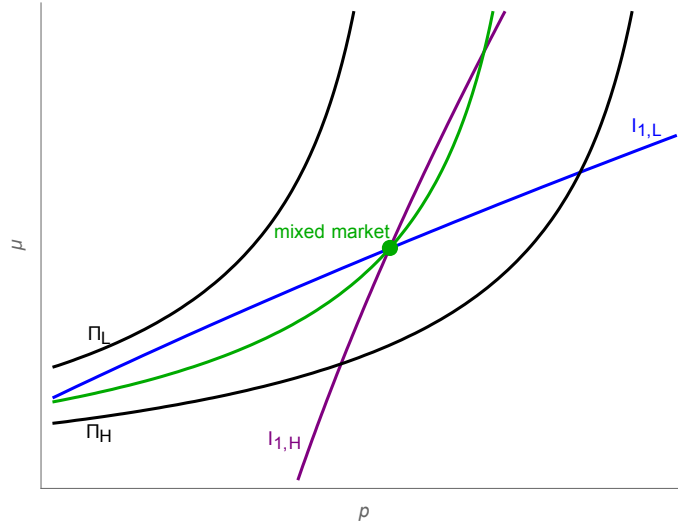


Figure 4: Cream-skimming deviation in the single-application case.

The result in Proposition 3 shows that this argument against pooling breaks down when workers can send sufficiently many applications. Before discussing the construction in the general case, we graphically illustrate the equilibrium in Figure 5 for the special case where  $N = 2$  and  $l = 1$ . There are three active markets: one with a low wage to which each low-type worker sends his first application  $(1, L)$ , one with a high wage to which each high-type worker sends his second application  $(2, H)$ , and one with an intermediate wage to which each low- (resp. high-) type worker sends his second (resp. first) application. We refer to the latter market as the *pooling market* since both types send applications there. Low types apply to the pooling market, hoping to receive an offer at the wage posted in that market but at the same time insuring themselves by also sending one application to a lower wage, where the chance of getting an offer is higher. In contrast, for high types, the pooling market represents the fallback option in case their application to a firm offering a higher wage fails. As in Figure 4, let  $\bar{p}$  and  $\bar{\mu}$ , respectively, denote the wage and the effective queue length in the pooling market. Note, however, that now the isoprofit (green) curve is different from the one in Figure 4: the effective composition in the pooling market is not equal to the population average but worse than that because high types only agree to trade at the pooling wage  $\bar{p}$  if they receive no offer in the high-wage market  $2, H$ .

To be able to claim that the described allocation constitutes an equilibrium, we need to verify that firms have no incentives to deviate by offering a different wage. In particular, we must rule out the profitability of cream-skimming deviations like the one we saw existed

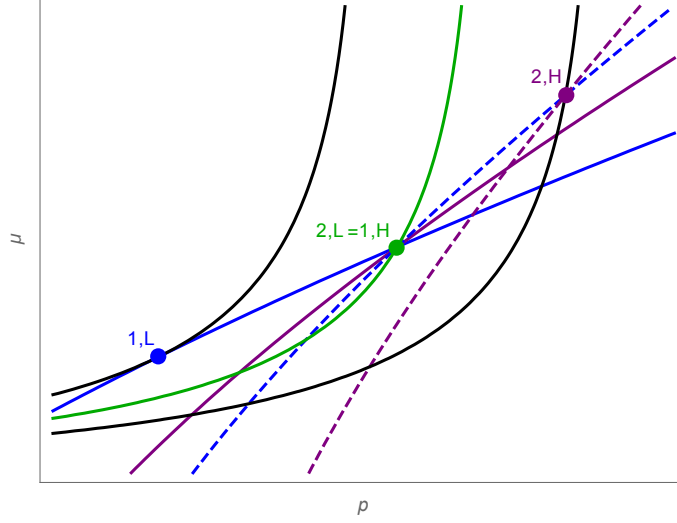


Figure 5: Wages and effective queue lengths in an equilibrium with a pooling market with  $N = 2$ .

for the pooling allocation in Figure 4, when workers could only send one application. To assess the profitability of a deviation to a different wage, we must again determine which type of worker this wage is more likely to attract. In Figure 5, the  $L$ -types' indifference curve associated with their second application (the dashed blue curve) is steeper than the  $H$ -types' indifference curve associated with their first application (solid purple curve). This happens because in the case of  $l = 1$ , the  $L$ -types' effective outside option for their second application,  $c_L + u_{1,L}^*$ , is higher than the  $H$ -types' outside option for their first application,  $c_H$ . We thus have a *reversal of the sorting condition* relative to Figure 4: this implies that it is not the high types who have the most to gain from applying to wages slightly above  $\bar{p}$  but rather the low types with their second application. Hence, a firm contemplating offering one of those wages expects to attract only  $L$ -type workers, rendering the deviation unprofitable. For wages below  $\bar{p}$ , it is again the low types who have the most to gain, this time by sending their first application. Hence, firms can only worsen the composition of the set of workers they attract by deviating to a wage slightly above or below  $\bar{p}$ , which means that no profitable cream-skimming deviation exists.<sup>11</sup>

The construction in Figure 5 can then be generalized as follows. Low and high types send, respectively, their first and their last  $l$  applications to separate markets, while all remaining applications are sent to a single pooling market with wage  $\bar{p}$ . The terms of trade in the  $L$ -

<sup>11</sup>The reversal of the sorting condition is somewhat reminiscent of the violation of the single crossing condition found by Chang (2018) in a competitive search model with two-dimensional private information. In that case, the outside option of traders is exogenous but subject to idiosyncratic (liquidity) shocks. In our setup, it is instead endogenous, so a given type of seller will have different preferences depending on which of his applications we are considering. The implications for the analysis of equilibria are then rather different.

type markets are the same as when their type is observable, while the terms of trade in the pooling market are such that  $L$ -types are indifferent between sending their  $l$ -th application to the pooling market or to the respective  $L$ -type market. The wages and effective queue lengths in the  $H$ -type markets are determined by the  $L$ -types'  $N$ -th incentive constraint. They can be constructed via the sequential procedure explained in Section 4.1.

In the proof of Proposition 3, we show that deviating to a price slightly below or above  $\bar{p}$  does not allow a firm to improve the composition of the applicant pool in market  $\bar{p}$ . This requires  $u_{l-1,L}^* + c_L < c_H$  and  $u_{N,L} + c_L \geq u_{N-l,H} + c_H$ , so that for wages just below  $\bar{p}$  the one who gains most is the  $L$ -type redirecting his  $l$ -th application and for wages just above  $\bar{p}$  it is the  $L$ -type deviating from his  $N$ -th application. While the first inequality is satisfied by the definition of  $l$ , the second follows from  $u_{l,L}^* + c_L \geq c_H$  and the fact that both types of workers send  $N - l$  applications to the pooling market and, therefore, have the same chance of receiving an offer there. Hence, firms deviating to wages slightly below or above  $\bar{p}$  expect to attract only low types. Finally, we need to verify that firms do not find it profitable to attract  $L$ -type workers at any off-path wages. This requires that the  $L$ -types' indifference curves in the candidate equilibrium do not intersect anywhere the isoprofit curve  $\Pi_L$ . Our assumption that  $v_H$  is sufficiently large implies that this property is satisfied.<sup>12</sup>

*Remark 1.* We should point out that, besides the equilibrium we illustrated in Figure 5 and whose existence we established more generally in Proposition 3, other partial pooling equilibria may exist. For instance, if the fraction of high types is sufficiently large, one can construct equilibria with a single pooling market where low types send fewer than  $l$  applications to separate markets and a larger number of applications than high types to a pooling market. In these equilibria, the composition of applicants in the pooling market is strictly worse than in the equilibrium we constructed. However, a fully pooling equilibrium in which both types send all their applications to the same market never exists. In that case, the same cream-skimming deviation argument as in the one-application case applies.

**Vanishing Search Frictions.** When the application capacity  $N$  increases, the equilibrium number of applications that are sent to separate markets remains unchanged and equal to  $l$ ,

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<sup>12</sup>For a numerical example of the bound for  $v_H$ , consider the specification  $v_L = 2, c_L = 0, c_H = 1, k = 0.1, N = 2$ . It can be verified that  $u_{1,L}^* + c_L \approx 1.40 > 1 = c_H$ , so we have  $l = 1$ . Hence, the candidate equilibrium, as described in Proposition 3, is of the partial pooling type (for all  $v_H > v_L$  and  $\sigma \in (0, 1)$ ). For  $\sigma = 0.5$ , the bound for  $v_H$  above which the partial pooling equilibrium is guaranteed to exist is  $\bar{v}_H \approx 2.33$ . If the share of low-type workers is reduced to  $\sigma = 0.3$ , this bound decreases to  $\bar{v}_H \approx 2.23$ . Hence, the higher the share of high-productivity workers, the more permissive the condition on  $v_H$  becomes. When  $v_H$  lies below this bound, an equilibrium with a single pooling market may not exist, as one of the  $L$ -type indifference curves going through the pooling market may intersect the  $L$ -type isoprofit curve. In such a case, firms have a profitable deviation by posting a wage higher than the pooling wage to attract low types. A partial pooling equilibrium can still be found for values  $v_H < \bar{v}_H$ , but a different, more elaborate construction involving multiple pooling markets is needed.

so all additional applications go to the pooling market. As  $N \rightarrow \infty$ , the indifference curves for the last applications sent by low types to the pooling market become increasingly steep, and hence the queue lengths in the  $H$ -type markets tend to  $\infty$  (see Figure 6). As a result, the probability with which an  $H$ -type worker is hired outside the pooling market converges to zero, and the effective composition in the pooling market converges to the population average. Since the pooling market lies on the  $L$ -type indifference curve associated with the  $l$ -th application, the effective queue length in the pooling market remains finite in the limit, as illustrated in Figure 6.

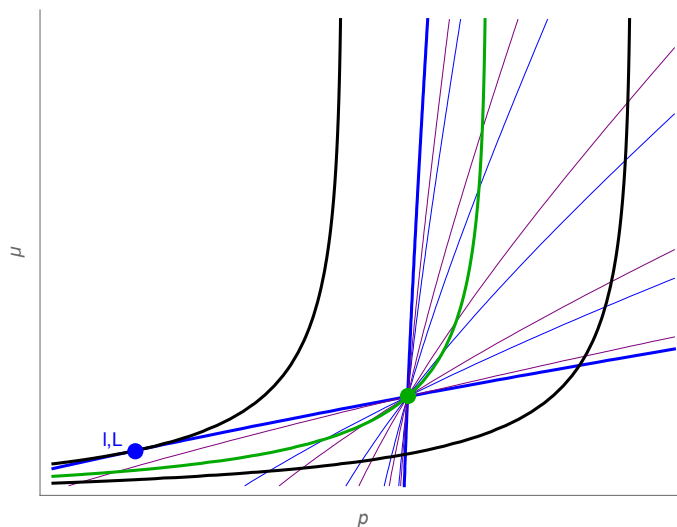


Figure 6: Wages and effective queue lengths in the equilibrium with one pooling market.

This last property has significant implications for the characteristics of the allocation obtained in the limit. Since the number of applications low and high types send to the pooling market tends to infinity as  $N \rightarrow \infty$ , a finite value of  $\mu$  implies that the probability with which any type ends up receiving an offer in the pooling market converges to one. That is, the distortion that adverse selection causes in workers' trading probability relative to the case with observable types disappears in the limit. In contrast, the probability that a firm hires a worker in the pooling market remains bounded away from one, and the wage remains bounded away from  $\sigma v_L + (1 - \sigma)v_H - k$ . Hence, there is excessive entry in the limit.<sup>13</sup> This is an important result as it shows that, in the presence of adverse selection, the inefficiency

<sup>13</sup>This result may suggest that a regulator would find it beneficial to tax entry in the pooling market. However, referring to Figure 6, we see that such a tax would move the green isoprofit curve to the northwest, thus moving to the left its intersection point with the indifference curve  $I_{l,L}$ , associated with the low types'  $l$ -th application, which exacerbates the excessive entry problem. What the regulator should do is somewhat the opposite: tax entry in the  $L$ -type markets and subsidize entry in the pooling market. The tax in the  $L$ -type markets leads to higher queue lengths in those markets, pushing upwards the indifference curve  $I_{l,L}$  and thereby increasing the queue length in the pooling market.

of the search equilibrium may not vanish in the limit when workers can send infinitely many applications to firms. The next proposition establishes this result formally.

**Proposition 4.** *Assume  $c_H < v_L - k$ . Then, as  $N \rightarrow \infty$ , at the equilibrium characterized in Proposition 3, the workers' probability of being hired in the pooling market converges to one and their market utility satisfies*

$$\lim_{N \rightarrow \infty} (\sigma u_{N,L} + (1 - \sigma)u_{N,H}) < \sigma(v_L - c_L) + (1 - \sigma)(v_H - c_H) - k, \quad (12)$$

*hence there is excessive entry in the limit.*

Proposition 4 follows directly from the equilibrium characterization in Proposition 3 for the case  $N > l$  and the arguments provided above. In Appendix B.1, we show that the result extends to all sequences of search equilibria with a single pooling market, as long as  $v_H$  is not too close to  $v_L$ . Intuitively, efficiency would require that the queue length in this pooling market tends to  $\infty$  and the price approaches  $\sigma v_L + (1 - \sigma)v_H - k$  as the number of applications per worker grows. We cannot have an equilibrium where only this market is active, since firms can profitably deviate to lower wages yielding lower queue lengths. Even if such wages only attract low-productivity workers, the deviation generates a strictly positive profit for the firm since these workers have a high gain from insuring themselves with their “early applications” (graphically, the indifference curves associated with those applications intersect the  $L$ -type isoprofit curve). To satisfy the incentive constraints of low-type workers, we thus need to have a sequence of sufficiently many  $L$ -type markets with wages below the pooling wage. This, however, would violate the incentive constraint of high-type workers, who would now also want to send some of their applications there. The formal argument in Appendix B.1 shows that this idea extends to cases in which some separating markets are active in addition to the pooling market. Hence, under any construction with a single pooling market, the queue length in this market must be sufficiently small, which means that firms hire with a probability smaller than one.

The intuition behind the result is that, in order to have efficiency, the probability of trade for any application sent to the pooling market should be negligible. This creates strong incentives for workers to hedge, which firms can profitably exploit.

### 4.3 Partial Convergence to Akerlof

As  $N$  grows, more and more firms and workers become connected with each other, leading to a reduction of the underlying search friction. In the limit, as  $N \rightarrow \infty$ , the exogenous search friction disappears altogether. It is then of interest to compare the properties of the equilibrium allocations we obtain in the limit with those of the equilibria of a Walrasian



market à la [Akerlof \(1970\)](#), where agents are price takers and there are no search frictions. Recall that, with binary types (and entry costs), there are two potential equilibria in an Akerlof economy: a separating one where only low types trade at price  $v_L - k$  and a pooling one where both types trade at price  $\sigma v_L + (1 - \sigma)v_H - k$ . The separating equilibrium exists when the lemons condition holds, while the pooling equilibrium exists if  $c_H \leq \sigma v_L + (1 - \sigma)v_H - k$ . When  $c_H \in [v_L - k, \sigma v_L + (1 - \sigma)v_H - k]$ , the Akerlof economy thus has two equilibria.

As shown in [Proposition 2](#) for the case  $c_H \geq v_L - k$ , as  $N \rightarrow \infty$ , all  $L$ -type workers are hired at a wage equal to their productivity, while  $H$ -type workers are forced out of the market. Hence, under the lemons condition, the search equilibrium allocation converges to the equilibrium found by [Akerlof \(1970\)](#). When adverse selection is instead mild ( $c_H < v_L - k$ ), we have seen in [Proposition 4](#) that there is a sequence of search equilibria where, in the limit as  $N \rightarrow \infty$ , all workers are hired in the same market, but there is excessive entry. The wage in the pooling market is then bounded away from the average productivity of these workers and thus does not correspond to the market price in the pooling equilibrium of the Akerlof economy. Moreover, the utility levels attained in the search equilibrium are lower than the ones in Akerlof's pooling equilibrium. Hence, there are sequences of search equilibria that do not converge to an equilibrium allocation with Walrasian markets.

Yet, as already noted in [Remark 1](#), when pooling markets can be sustained in equilibrium, multiple equilibria exist. An important question is thus whether we can find sequences of search equilibria that converge to the efficient pooling equilibrium of [Akerlof \(1970\)](#) when  $c_H$  is below the average productivity  $\sigma v_L + (1 - \sigma)v_H - k$ . The following result shows that this is indeed possible. Hence, even if not *all* sequences of equilibria converge to a Walrasian equilibrium as in [Akerlof \(1970\)](#), any equilibrium of [Akerlof \(1970\)](#) can be obtained as the limit of *some* sequence of search equilibria as  $N \rightarrow \infty$ .

**Proposition 5.** *Assume  $c_H < \sigma v_L + (1 - \sigma)v_H - k$ . There exists a threshold  $\bar{v}_H$  such that for all  $v_H \geq \bar{v}_H$  the following holds.<sup>14</sup> For each  $\varepsilon > 0$  arbitrarily close to zero, we can find some  $N_\varepsilon$  such that for all  $N > N_\varepsilon$ , an equilibrium exists where*

$$\sigma u_{N,L} + (1 - \sigma)u_{N,H} \geq \sigma(v_L - c_L) + (1 - \sigma)(v_H - c_H) - k - \varepsilon. \quad (13)$$

Starting with the case  $c_H < v_L - k$ , it is useful to recall that for the equilibria with a single pooling market, efficiency fails in the limit (see [Proposition 4](#)) because the effective queue length in the pooling market is finite, which is needed to ensure that incentive constraints

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<sup>14</sup>The bound for  $v_H$  needed in this result is the same as the one of [Proposition 3](#); see [Appendix A.3](#) for an explicit characterization.

are satisfied and no profitable deviation exists; hence too many firms enter in equilibrium. In the proof of Proposition 5 in the Online Appendix, we show that, under the same parameter conditions, a sequence of equilibria with two pooling markets exists where, as  $N$  tends to infinity, the probability that both types of workers are hired converges to one and, in addition, entry is efficient so that firms hire with probability one. The key idea is the following. The first pooling market takes care of the incentives of workers to hedge by sending some applications to firms posting lower wages. But now a second pooling market is active and the wage in this market increases with the total number of applications so that the queue length approaches infinity in the limit. Since almost all applications are sent to the second pooling market, firms' entry is efficient in the limit. The construction is illustrated in Figure 7.

Turning our attention to the case  $c_H \in [v_L - k, \sigma v_L + (1 - \sigma)v_H - k]$ , it is easy to see that incentive compatibility for high types is not an issue here. Since the lemons condition is satisfied and the wage in any  $L$ -type market is always below  $v_L - k$ ,  $H$ -type workers will never want to send any of their applications to such markets. This implies that we can now let the index of the first application that  $L$ -types send to the pooling market grow with  $N$ , to get an arbitrarily high effective queue length in this market. Hence, in the limit, firms hire with probability one at a wage equal to the average productivity (minus entry costs). Note further that, by varying how fast the index of this first pooling application grows with  $N$ , one can support many additional equilibria in the limit, whose outcomes lie between the two equilibrium allocations found by Akerlof, featuring complete pooling and complete separation.

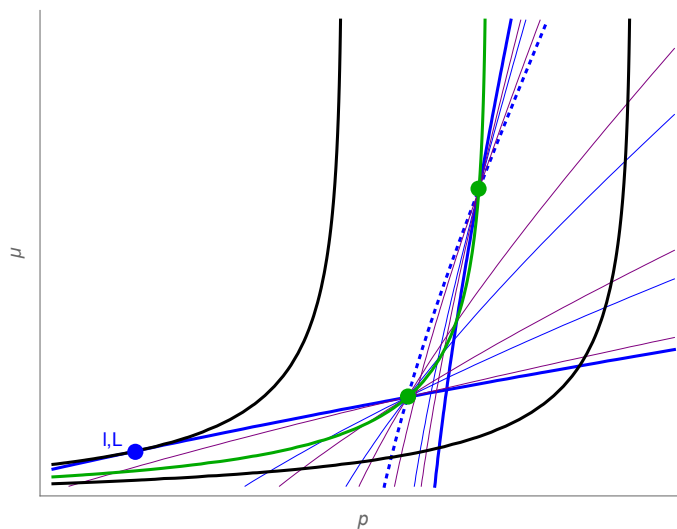


Figure 7: Wages and effective queue lengths in an equilibrium with two pooling markets.

To sum up, for any equilibrium in Akerlof (1970), we can find a sequence of search

equilibria that converges to the same allocation as  $N \rightarrow \infty$ . When  $c_H < \sigma v_L + (1 - \sigma)v_H - k$  holds, other equilibria exist and the multiplicity persists in the limit as the search friction vanishes. This stands in contrast with the findings of Kircher (2009) for the observable type case, where search equilibria are always unique. More strikingly, it also stands in contrast with the results obtained when firms compete strategically in contract offers without search frictions. Both Attar et al. (2011), with general contracts under non-exclusivity, and e.g., Mas-Colell et al. (1995), with exclusive contracting when traded quantities are restricted to  $\{0, 1\}$ , always find a unique equilibrium outcome, given by the Pareto-dominant equilibrium allocation in Akerlof (1970).

A key role behind this difference in equilibrium outcomes is played by the fact that in our environment, firms are interested in hiring at most one worker, i.e., firms compete for workers but face a capacity constraint. Without any capacity constraint, firms would find it profitable to deviate from the separating equilibrium by posting higher wages to attract all workers. In contrast, doing so when they have a capacity constraint would only attract the workers who are most keen to apply to higher wages and these are the low types.<sup>15</sup> Our analysis therefore suggests that the decentralized property of markets and the fact that traders have limited market power have important consequences in environments with adverse selection.

*Remark 2.* Competitive search models with adverse selection and a single opportunity to contact a potential trading partner, such as Guerrieri et al. (2010), feature the stark property that the equilibrium outcome does not depend on the type distribution. Thus, the presence of low types severely distorts the equilibrium allocation for high types, even if the fraction of low types in the population is very small. The discontinuity in this allocation at the point where such fraction is zero is sometimes viewed as unappealing (see, for example, Lester et al., 2019). The same criticism applies to our model if we consider the separating equilibrium. However, as Proposition 5 shows, if  $\sigma$  is close to 0, other equilibria with partial pooling exist and the efficient outcome can be approached in the limit as  $N \rightarrow \infty$ . Hence, if we focus on the most efficient equilibrium, we can say that, compared to the single-application benchmark, the discontinuity becomes smaller when workers can send multiple applications and disappears when  $N \rightarrow \infty$ .

## 5 Welfare Implications and Policy

When workers' types are publicly observable, the only effect of increasing the number  $N$  of applications workers can submit is to alleviate the search friction. Hence, the welfare of all workers in equilibrium, and thus overall ex-ante welfare, unambiguously increases with  $N$ .

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<sup>15</sup>What ultimately matters is the presence of *some* capacity constraint, not that the capacity is one.

In contrast, when the type of a worker is only privately observed by him, increasing  $N$  not only mitigates the search friction but also affects, as discussed earlier, the set of allocations that are incentive-compatible. In particular, the possibility of using the different liquidity of markets with distinct queue lengths to screen workers is weakened when they can hedge the risk of not being hired by applying to multiple markets. The welfare consequences of allowing multiple applications are thus more complex. In this section, we examine the effect of changes in the meeting technology, captured by changes in  $N$ , on the welfare of market participants.

The fact that screening workers becomes more difficult as  $N$  increases can manifest itself in two ways. First, in the separating equilibrium, a larger  $N$  increases the congestion in high-type markets. The direct effect of a larger number of applications may initially outweigh this force, but the increased congestion ultimately dominates as  $N$  becomes large enough. As we saw, high types are driven out of the market and thus unambiguously lose when  $N \rightarrow \infty$ . Second, the difficulty of screening workers via queue lengths may destroy the possibility of separation altogether, making partial pooling a necessary feature of the equilibrium. As discussed in the previous section, this may lead to efficiency as  $N$  becomes large.

**Comparative Statics for Small  $N$ .** Moving the focus away from the limit, it is interesting to consider the welfare effects for workers of smaller increments of their application capacity. To this end, we will focus on the other extreme, where the number of applications workers can send increases from  $N = 1$  to  $N = 2$ . When  $N = 1$  the equilibrium is always separating with two active markets, whereas for the case  $N = 2$ , we saw that two outcomes are possible. If  $c_H < v_L - k$  and  $l = 1$ , there is an equilibrium in which workers send one of their applications to a pooling market; otherwise, the equilibrium remains perfectly separating as in the case of  $N = 1$ .

Considering first the latter case, it is clear that the  $L$ -type workers benefit from an increase in the capacity  $N$ . Since their equilibrium allocation is not affected by incentive constraints and is thus the same as in the observable type case, their expected payoff must increase. As a result of this increase, the indifference curve for their second application,  $I_{2,L}$ , is steeper than the one for their first application.

With regard to the welfare of high types, there are two countervailing effects. An increase in  $N$ , on the one hand, reduces the chance of any single application being successful since, due to the steeper slope of  $I_{2,L}$ , the incentive constraints imposed on the trading probability of  $H$ -type workers are tighter. On the other hand, by sending two applications, high types can at least partly offset the risk that any given application fails. The first effect disappears—hence high types gain when  $N$  increases—if the incentive constraints of the low-type workers are slack so that the terms of trade in the  $H$ -type markets are not affected by these constraints.

This happens, for instance, if the gains from trade with  $H$ -type workers,  $v_H - c_H - k$ , are sufficiently small.

In contrast, a sufficient condition for  $H$ -type workers to unambiguously lose when moving from  $N = 1$  to  $N = 2$  is a sufficiently small entry cost  $k$ . When entry costs are negligible, low types already extract almost all the gains from trade with their first application. Their opportunity cost to send their second application to one of the high-type markets is then very small, which means they are deterred from doing so only if the trading probability in such markets is close to zero. Hence, high-type workers are essentially driven out of the market already when workers send two applications. It then follows that the ex-ante welfare of workers is lower for  $N = 2$  than for  $N = 1$  since low types gain very little from the additional application, while the payoff loss for high-type workers is non-negligible.

A similar picture arises when an increase from  $N = 1$  to  $N = 2$  implies a switch from the separating equilibrium to an equilibrium with partial pooling (that is, when  $c_H < v_L - k$  and  $l = 1$ ). Since  $L$ -type workers are better off when they can pool with  $H$ -type workers, their gain from an increase in the application capacity is even larger in this case. The welfare effect for  $H$ -type workers remains ambiguous and now depends on the share of  $L$ -type workers in the economy. To illustrate this, let us focus again on the limit case where firms' entry cost vanishes. As already noticed, for  $k$  small,  $L$ -type workers extract almost all the gains from trade with their first application: having assumed  $\lim_{k \rightarrow 0} u_{L,1}^* + c_L = v_L > c_H$  and  $c_H < v_L - k$ , we indeed have  $l = 1$ . Letting  $U_H(N)$  denote the equilibrium utility of  $H$ -type workers when the total number of applications workers can send is  $N$ , we can show the following:

**Proposition 6.** *For any  $k$  sufficiently small, there exists some  $\sigma_k \in (0, 1)$  such that  $U_H(1) \leq U_H(2)$  if and only if  $c_H < v_L - k$  and  $\sigma < \sigma_k$ .*

We already explained why, for  $k$  sufficiently small,  $U_H(1) \leq U_H(2)$  is violated when the lemons condition holds, so we focus on the case  $c_H < v_L - k$ . In the limit as  $k \rightarrow 0$ , the separating equilibrium for  $N = 1$  has low types trading with probability one at price  $v_L$ . Similarly, the wage in the  $H$ -type market approaches  $v_H$  as  $k \rightarrow 0$ , but, due to incentive compatibility, the workers' trading probability in that market is strictly smaller than one.<sup>16</sup> In the case of  $N = 2$ , the equilibrium features partial pooling. The terms of trade in the  $L$ -type market where low types send their first application remain unchanged, while the queue length in the  $H$ -type market where high types send their second application is higher than in the single-application case. Whether high types gain or lose from an increase

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<sup>16</sup>The limit case  $k \rightarrow 0$  is another way of modeling vanishing search frictions. As argued in the Introduction and seen here, for  $N = 1$ , the qualitative features of the search equilibrium are unaffected when  $k$  vanishes.

in the application capacity depends then on whether the benefit of sending the additional application to the pooling market outweighs the cost of facing a higher queue length in the  $H$ -type market. For the gain to dominate, the wage in the pooling market has to be sufficiently high. This requires the average quality of workers in the pooling market to be sufficiently good and, hence, the fraction of low-productivity workers in the population to be sufficiently low.

**Policy Implications.** A natural question is to what extent policy can improve equilibrium outcomes in our environment. We discuss two kinds of interventions, which differ in the instruments available to the policymaker. This discussion allows us to gain some insights into the forces at play and the trade-offs faced by the policymaker in the design of these interventions.

First, consider the case in which the policymaker can only control the degree of search frictions in the market (i.e., set the level of  $N$ ), e.g. by creating a trading platform that facilitates meetings. As mentioned, a higher value of  $N$  is always welfare-improving under perfect information (Kircher, 2009). It readily follows from the discussion above that this is no longer true with adverse selection: depending on parameter values,  $N = 2$  may lead to either higher or lower ex-ante welfare than  $N = 1$ . A similar picture emerges when we compare  $N = 1$  with  $N \rightarrow \infty$ . Intuitively, although search frictions inhibit trade, they can serve a socially useful role in environments with adverse selection by facilitating screening. The policymaker has to balance these forces and will, therefore, not always prefer larger values of  $N$ . This result is consistent with the presence of application caps in various real-life markets. For example, the number of universities that high-school students in the UK can apply to was six until 2008. After an evaluation by the Department for Education and Skills (2006), this number was then reduced to five in order to improve the process. Similarly, workers can apply to at most 4 of the 15 different schemes in the United Kingdom’s Civil Service Fast Stream per annual recruitment cycle.

Alternatively, imagine a policymaker that takes  $N$  as given but has the power to determine which submarkets are active, e.g., by imposing price controls, and to affect the tightness of these markets, e.g., by imposing taxes or subsidies on entry. By doing so, the policymaker operates effectively as a social planner who assigns workers and firms to different submarkets subject to the search friction, incentive constraints, and individual rationality constraints. For instance, the policymaker could implement perfect pooling by assigning all firms and workers to a single submarket. In many environments with adverse selection, pooling—or, more generally, some cross-subsidization between types—is socially beneficial as it allows to relax incentives. Davoodalhosseini (2019) establishes this formally for the environment with  $N = 1$  considered by Guerrieri et al. (2010). When  $N$  is larger than 1, the planner’s

problem is more complex and new trade-offs emerge. While there continues to be a benefit to pooling the applications of different types of workers, there is also a benefit to separating the different applications of each worker, as shown by Kircher (2009).

To illustrate this, we consider the case in which the outside options of the two types of workers are close to each other and workers send two applications. For this case, the following proposition establishes that a planner can always increase ex-ante welfare with respect to the equilibrium allocation by creating two separate submarkets designed in such a way that both types of workers choose to send one application to each market.<sup>17</sup> Furthermore, this allocation strictly dominates full pooling, i.e., the creation of a single submarket in which all workers send all their applications.

**Proposition 7.** *For  $c_H$  sufficiently close to  $c_L$ , a planner who designs two markets can generate a higher level of surplus than both the market equilibrium and a planner who designs a single market (thus implementing full pooling of types and applications).*

We show in the proof that no taxes or transfers are needed in order to achieve a higher surplus, i.e., price controls suffice.

## 6 Conclusion

We study a market in which firms post wages to attract applications from workers who have private information about their productivity. We demonstrate how increasing contacts in such a market not only decreases search frictions but also reduces firms' screening ability. The subtle interaction between these forces generates a rich set of outcomes. In particular, we find that—in contrast to a situation where each worker can send a single application—the existence of a fully separating equilibrium is only guaranteed if adverse selection is sufficiently severe. When this condition is not satisfied, and workers can send sufficiently many applications, the equilibrium features the presence of pooling markets and multiple equilibria exist.

We analyze the properties of these equilibria as the number of applications grows large and, hence, search frictions vanish. While the allocation in the separating search equilibrium converges to the one with Walrasian markets à la Akerlof (1970), the same is not true for all equilibria with pooling markets: some of them exhibit frictional trade and thus inefficiency in the limit due to excessive entry. Finally, we show that, with adverse selection, the welfare

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<sup>17</sup>Note that this would be the equilibrium outcome if  $c_L$  were actually equal to  $c_H$ . Since workers would have identical preferences in that case, firms would have no way of separating them. The equilibrium allocation would then be the same as in the observable type case, described in Section 3.2, with the average productivity  $\sigma v_L + (1 - \sigma)v_H$  replacing the type-specific one  $v_i$ .

consequences of facilitating contacts among market participants are ambiguous. A variety of policy implications, some of them rather surprising, can be drawn from our analysis.

In our model, we exogenously fixed the number of applications  $L$ - and  $H$ -type workers can send and assumed this number is the same for both types. The benefits of sending additional applications are, however, generally different for the two types of workers. Hence, if workers could choose how many applications to send, facing a fixed cost per application,  $H$ - and  $L$ -type workers may make different choices. In Online Appendix D, we extend the analysis to this case and show that the total number of applications sent by  $L$ -type workers is, in fact, higher than that for  $H$ -type workers. As a consequence, high types send fewer applications to separate markets and, in many situations, do not trade in such markets, even away from the limit. Hence, accounting for workers' application incentives on the extensive margin reinforces the effect of adverse selection in our environment. Apart from this difference, we show that the main properties of equilibrium allocations remain valid when the number of applications sent by each type is endogenously determined.

An interesting avenue for future research would be to extend our model to a dynamic setting. We expect that our results remain unchanged if matches are long-lived, as long as the unemployment pool is stationary and firms do not learn the types of their hires. Learning would add a new interesting dimension and could, for example, endogenously generate heterogeneity in outside options. We therefore expect that the trade-offs characterized in our paper will remain important. In a labor market context, an interesting question would also be to what extent the insights of our model could be generated through on-the-job search rather than simultaneous search, as these mechanisms are known to often have similar effects (see [Burdett and Mortensen, 1998](#) versus [Burdett and Judd, 1983](#) in random search, or [Delacroix and Shi, 2006](#) and [Menzio and Shi, 2010](#) versus [Kircher, 2009](#) in directed search).<sup>18</sup>

## Appendix A Proofs

In what follows, we will denote by

$$I_i(u_{n-1,i}, u_{n,i}) = \{(\mu, p) : \psi(\mu)(p - c_i - u_{n-1,i}) = u_{n,i} - u_{n-1,i}\}$$

type  $i = L, H$ 's indifference curve associated with utility levels  $u_{n-1,i}, u_{n,i}$  and by

$$\Pi_\gamma = \{(\mu, p) : \eta(\mu)(\gamma v_L + (1 - \gamma)v_H - p) = k\}$$

the firms' isoprofit curve when the fraction of  $L$ -types is  $\gamma$ .

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<sup>18</sup>We thank Guido Menzio for this insight.



## A.1 Proof of Proposition 1

We first show that in any separating equilibrium, the terms of trade in an  $L$ -type market attracting the  $n$ -th application of low-type workers is described as a tangency point of the isoprofit curve  $\Pi_L$  and the indifference curve  $I_L(u_{n-1,L}, u_n, L)$ . By Condition 1 of Definition 1, we have  $(\mu_{n,L}, p_{n,L}) \in I_L(u_{n-1,L}, u_n, L)$ . Assuming now that  $(\mu_{n,L}, p_{n,L})$  was not a tangency point of  $I_L(u_{n-1,L}, u_n, L)$  with  $\Pi_L$ , there would exist some  $(\tilde{\mu}, \tilde{p}) \in I_L(u_{n-1,L}, u_n, L)$  such that

$$\eta(\mu(\tilde{p}))(\gamma(\tilde{p})v_L + (1 - \gamma)(\tilde{p})v_H - p) \geq \eta(\tilde{\mu})(v_L - \tilde{p}) > k,$$

where the first inequality follows from  $\gamma(\tilde{p}) \in [0, 1]$  and, by the market-utility condition,

$$\mu(\tilde{p}) = \max \{ \mu' \geq 0 : (\mu', p) \in I_i(u_{n-1,i}, u_n, i) \text{ for some } i = L, H, n = 1, \dots, N \}.$$

Hence, firms would have a profitable deviation, so all active  $L$ -type markets  $(\mu_{n,L}, p_{n,L})$ ,  $n = 1, \dots, N$  must be tangency points of the respective indifference curves with the isoprofit curve  $\Pi_L$ . Starting from the  $L$ -types' first application, where the outside option is endogenous, an iterative argument then implies  $\mu_{n,L} = \mu_{n,L}^*$ ,  $p_{n,L} = p_{n,L}^*$  and  $u_{n,L} = u_{n,L}^*$  for all  $n = 1, 2, \dots, N$ . The  $L$ -types' allocation in a separating equilibrium thus coincides with the one obtained for the observable type case.

Next, we consider the  $H$ -type markets in a candidate separating equilibrium. Given the lemons condition  $c_H \geq v_L - k$ , there is a unique intersection between the upper envelope of the low type's indifference curves  $I_L(u_{n-1,L}^*, u_n^*, L)$ ,  $n = 1, \dots, N$  and  $\Pi_H$ . This intersection is with  $I_L(u_{N-1,L}^*, u_N^*, L)$ . Hence, the only incentive constraint potentially binding is the one associated with the  $L$ -type's  $N$ -th application. Let  $(\underline{\mu}_H, \underline{p}_H)$  be the (unique) value of  $(\mu_{n,H}, p_{n,H}) > (\mu_{N,L}^*, p_{N,L}^*)$  satisfying  $(\mu_{n,H}, p_{n,H}) \in I_L(u_{N-1,L}^*, u_N, L)$  and  $(\mu_{n,H}, p_{n,H}) \in \Pi_H$ .

Suppose first  $\mu_{n,H}^* \geq \underline{\mu}_H$  for all  $n \geq 1$ . In this case incentive constraints are not binding. We set for all  $n$ ,  $\mu_{n,H} = \mu_{n,H}^*$  and  $u_{n,H} = u_{n,H}^*$ . Notice that the associated wages satisfy  $p_{1,L}^* < p_{2,L}^* < \dots < p_{N,L}^* < p_{1,H}^* < p_{2,H}^* < \dots < p_{N,H}^*$ . For each  $p$ , we set

$$\mu(p) = \max \{ \mu : \psi(\mu)(p - c_i - u_{n-1,i}) \leq u_{n,i}^* - u_{n-1,i}^* \text{ for some } i \in \{L, H\}, n \leq N \}$$

and  $\gamma(p) = 0$  for all  $p$  such that the previous max is attained at  $i = H$  and  $\gamma(p) = 0$  otherwise. It can be easily verified that this specification of the functions  $\mu$  and  $\gamma$  satisfies the market utility condition.

If  $\mu_{1,H}^* < \underline{\mu}_H$ , we follow a recursive procedure to find the effective queue lengths and market utilities in the  $H$ -type markets. We start by setting  $\mu_{1,H} = \underline{\mu}_H$  and  $u_{1,H} =$

$\psi(\mu_H)(\underline{p}_H - c_H)$ . Given  $u_{1,H}$ , we calculate the unconstrained solution of  $\mu_{2,H}$ . Setting  $n = 2$ , the solution is determined by

$$(1 - e^{-\mu_{n,H}} - \mu_{n,H}e^{-\mu_{n,H}})(v_H - c_H - u_{n-1,H}) = k \quad (\text{A.1})$$

If the value of  $\mu_{2,H}$  solving this condition is weakly greater than  $\underline{\mu}_H$ , it is the effective queue length in market  $(2, H)$ . The associated market utility is

$$u_{n,H} = e^{-\mu_{n,H}}(v_H - c_H) + (1 - e^{-\mu_{n,H}})u_{n-1,H} \quad (\text{A.2})$$

The queue lengths and market utilities of the remaining markets ( $N > 2$ ) are then determined by the same set of conditions.

If instead  $\mu_{2,H}$  solving (A.1) for  $n = 2$  is strictly smaller than  $\underline{\mu}_H$ , we set  $\mu_{2,H} = \underline{\mu}_H$ . The market utility  $u_{2,H}$  is then determined by (A.2). We repeat the procedure for all  $n > 2$ . Having fixed market utilities in this way, the functions  $\mu, \gamma$  can be specified as follows. For all  $p < \underline{p}_H$  we set  $\gamma(p) = 1$  and for all  $p \geq \underline{p}_H$  we set  $\gamma(p) = 0$ . For wages  $p < \underline{p}_H$ , the queue length  $\mu(p)$  is then determined as the upper envelope of the indifference curves  $I_L(u_{n-1,L}^*, u_{n,L}^*)$ ,  $n = 1, \dots, N$ ; for wages  $p \geq \underline{p}_H$ , it is determined as the upper envelope of the indifference curves  $I_H(u_{n-1,H}, u_{n,H})$ ,  $n = 1, \dots, N$  with  $\{u_{n,H}\}_{n=1}^N$  specified by the recursive procedure.

*No profitable deviations.* The incentives of  $L$ -types are satisfied by construction. The equilibrium thus exists if and only if 1)  $H$ -types cannot profit from sending a subset of their applications to one of the  $L$ -type markets, and 2) firms cannot profit from posting an alternative wage.

Regarding incentive compatibility of  $H$ -type workers, notice that wages in the  $L$ -type markets are bounded above by  $v_L - k$ . The assumption  $c_H \geq v_L - k$  then implies that the wages in the  $L$ -type markets are strictly below the  $H$ -type's outside option, hence sending applications to such markets cannot be profitable for  $H$ -types, independent of how many application workers can send.

As to requirement 2, recall that we set  $\gamma(p) = 1$  for all off-path wages  $p < \underline{p}_H$  and  $\gamma(p) = 0$  for all  $p \geq \underline{p}_H$  so as to satisfy the market utility condition (6). Since the  $L$ -type indifference curves,  $I_L(u_{n-1,L}^*, u_{n,L}^*)$ ,  $n = 1, \dots, N$ , are tangent to  $\Pi_L$ , and the  $H$ -type indifference curves are either tangent (if  $L$ -type incentives are slack) or cut  $\Pi_H$  from below (if  $L$ -type incentives bind), this implies

$$\eta(\mu(p))(\gamma(p)v_L + (1 - \gamma(p))v_H - p) \leq k,$$

as can be easily verified. Hence, in the candidate separating equilibrium, no market participant has incentives to deviate.  $\square$

## A.2 Proof of Proposition 2

A straightforward extension of Proposition 6 in Kircher (2009) shows that  $\lim_{N \rightarrow \infty} u_{N,L}^* = v_L - c_L - k$ . We now want to prove that the probability with which the  $H$ -type is hired in equilibrium tends to zero. Since wages are bounded above by the firms' valuation (net of entry cost), this directly implies  $\lim_{N \rightarrow \infty} u_{N,H} = 0$ . Letting  $(\mu_{1,H}(N), p_{1,H}(N))$  describe the terms of trade in market  $(1, H)$  when the number of available applications is  $N$ , we can define the probability of being hired when sending  $\tilde{N}$  applications to market  $(1, H)$ :

$$\alpha(\tilde{N}, N) := 1 - \left(1 - \left(1 - e^{-\mu_{1,H}(N)}\right) / \mu_{1,H}(N)\right)^{\tilde{N}}.$$

Since  $\mu_{1,H} \leq \mu_{n,H}$  for all  $n$ ,  $\alpha(N, N)$  is an upper bound for the equilibrium probability with which the  $H$ -type is hired when sending  $N$  applications.

Now suppose each worker has available  $2n + j$  applications where  $n \in \mathbb{N}$  and  $j \in \{0, 1\}$ . If the  $L$ -type sends no applications to any of the  $H$ -type markets, his payoff is  $u_{2n+i,L}^* < v_L - c_L - k$ . If instead he sends  $n + j$  applications to the  $L$ -markets with the lowest  $n + j$  wages and  $n$  applications to market  $(1, H)$ , his payoff is

$$\alpha(n, 2n + j)(p_{1,H}(2n + j) - c_L) + (1 - \alpha(n, 2n + j))u_{n+j,L}^*. \quad (\text{A.3})$$

In equilibrium, (A.3) must be smaller than  $v_L - c_L - k$ . Since  $\lim_{n \rightarrow \infty} u_{n+j,L}^* = v_L - c_L - k$  and  $p_{1,H}(2n + j) - c_L > c_H - c_L > v_L - c_L - k$ , this requires  $\lim_{n \rightarrow \infty} \alpha(n, 2n + j) = 0$ .

Finally, we want to show that  $\alpha(n, 2n + j) \rightarrow 0$  implies  $\alpha(2n + j, 2n + j) \rightarrow 0$ . To this end, notice that the function  $\alpha(\cdot, 2n + j) : \mathbb{R} \rightarrow [0, 1]$  is strictly increasing and strictly concave with  $\alpha(0, 2n + j) = 0$ . Hence,

$$\alpha(n, 2n + j) > \frac{n}{2n + j} \alpha(2n + j, 2n + j).$$

Given  $\lim_{N \rightarrow \infty} n/(2n + j) = 1/2$ , this inequality and the property  $\lim_{n \rightarrow \infty} \alpha(n, 2n + j) = 0$  imply  $\lim_{n \rightarrow \infty} \alpha(2n + j, 2n + j)/2 = 0$ . Hence,  $\lim_{N \rightarrow \infty} \alpha(N, N) = 0$ . As we stated above,  $\alpha(N, N)$  is an upper bound for the equilibrium probability with which  $H$ -type workers are hired. In the limit this type is hired with probability zero and  $\lim_{N \rightarrow +\infty} u_{N,H} = 0$ .  $\square$

### A.3 Proof of Proposition 3

**Separating equilibrium.** The candidate separating equilibrium follows the same construction as in Appendix A.1:  $L$ -type markets are as in the observable-type case,  $H$ -type markets are constructed recursively so as to satisfy the  $L$ -types' incentive constraint with respect to their  $N$ -th application. Given that  $v_H$  is sufficiently large (see below for the construction of an explicit bound), there is again a unique intersection between the upper envelope of the low type's indifference curves  $I_L(u_{n-1,L}^*, u_{n,L}^*), n = 1, \dots, N$  and  $\Pi_H$ , namely with  $I_L(u_{N-1,L}^*, u_{N,L}^*)$ . The separating equilibrium constructed in Appendix A.1 is thus the only candidate for such equilibrium.

*No profitable deviations.* By the same argument as in Appendix A.1,  $L$ -types and firms have no profitable deviation. In contrast to the case of severe adverse selection, the  $H$ -types' incentive constraints, however, may now be violated. Letting  $\psi_{n,i} \equiv \psi(\mu_{n,i})$  denote the probability of receiving an offer in market  $i, n$ , incentive compatibility generally requires that for any  $(n, i) \neq (n', i')$  with  $u_{n,i} + c_i \leq u_{n',i'} + c_{i'}$ , we have  $\psi_{n,i} \geq \psi_{n',i'}$ , which follows from standard arguments. Incentive compatibility for the  $L$ -type requires that  $\mu_{1,H}$  is weakly greater than  $\underline{\mu}_{1,H}$ , which is strictly greater than  $\mu_{n,L}^*$  for all  $n \leq N$ . This is then compatible with the incentive constraints of  $H$ -types if and only if  $u_{N-1,L}^* + c_L \leq c_H$ , or, equivalently, if and only if  $N \leq l$ . Hence, given  $c_H < v_L - k$  and  $v_H$  sufficiently large, a separating equilibrium exists if and only if  $N \leq l$ .

**Partial Pooling Equilibrium.** We begin the proof by constructing a candidate equilibrium where  $L$ -types send the last  $m$  applications to the pooling market, while  $H$ -types send the first  $m'$  applications to that market and, for now, we allow  $m$  to differ from  $m'$ . The first  $N - m$  applications of the  $L$ -type are sent to separate markets, which are the same as in equilibrium with observable types (or the separating equilibrium). Hence, the effective queue lengths and market utilities in these markets are  $\mu_{n,L} = \mu_{n,L}^*$  and  $u_{n,L} = u_{n,L}^*$ , for all  $n \leq N - m$ .

We will first determine the effective queue lengths and wages in the pooling market and the  $H$ -type markets, taking as given the number of applications the two types send to the pooling market,  $m$  and  $m'$ , and the composition in that market, given by the effective fraction  $\bar{\gamma}$  of  $L$ -type workers. Let  $\bar{\mu}$  and  $\bar{p}$  be, respectively, the effective queue length and the wage in the pooling market. We set their values to be such that the  $L$ -type is indifferent between sending the  $N - m$ -th application to market  $(N - m, L)$  and sending it to the pooling market.

The terms of trade in the pooling market  $(\bar{\mu}, \bar{p})$  must then satisfy

$$(\bar{\mu}, \bar{p}) \in (\Pi_{\bar{\gamma}} \cap I_L(u_{N-m-1,L}^*, u_{N-m,L}^*)) . \quad (\text{A.4})$$

It is easy to verify that this condition has a unique solution on the domain  $(\bar{\mu}, \bar{p}) > (\mu_{N-m,L}^*, p_{N-m,L}^*)$ . Let us denote such value with  $\bar{\mu}(\bar{\gamma}), \bar{p}(\bar{\gamma})$  and set  $\bar{\mu} = \bar{\mu}(\bar{\gamma}), \bar{p} = \bar{p}(\bar{\gamma})$ .

To find the utility gains  $L$ - and  $H$ -types attain by trading in the pooling market, it is useful to define the probability of receiving an offer in a market with effective queue length  $\mu$  when sending  $n \geq 1$  applications to that market:

$$\beta(n, \mu) := 1 - (1 - \psi(\mu))^n \quad (\text{A.5})$$

The market utility of  $H$ -type workers associated with their first  $m'$  applications is then  $u_{n,H}(\bar{\gamma}) = \beta(n; \bar{\mu}(\bar{\gamma}))(\bar{p}(\bar{\gamma}) - c_H), n = 1, \dots, m'$ , while the market utility of  $L$ -type workers associated with their last  $m$  applications is  $u_{N-m+n,L}(\bar{\gamma}) = \beta(n; \bar{\mu}(\bar{\gamma}))(\bar{p}(\bar{\gamma}) - c_L) + (1 - \beta(n, \bar{\mu}(\bar{\gamma})))u_{N-m,L}^*, n = 1, \dots, m$ .

To determine the separating markets to which  $H$ -types send their  $(m+1)$ -th and subsequent applications, let  $(\mu_H(\bar{\gamma}), p_H(\bar{\gamma}))$  be the unique solution of

$$(\mu_H, p_H) \in (\Pi_H \cap I_L(u_{N-1,L}(\bar{\gamma}), u_{N,L}(\bar{\gamma})))$$

satisfying  $(\mu_H, p_H) > (\bar{\mu}, \bar{p})$ . Note that  $p_H(\bar{\gamma})$  is the lowest wage to which only  $H$ -types are willing to apply. We then need to compare the utility they attain by sending applications to  $p_H(\bar{\gamma})$  and to higher wages, at which incentive constraints no longer bind. When  $H$ -types send  $n \geq 1$  applications to market  $p_H(\bar{\gamma})$ , they attain a utility level

$$u_{m'+n,H} = \beta(n; \mu_H(\bar{\gamma}))(p_H(\bar{\gamma}) - c_H) + (1 - \beta(n, \mu_H(\bar{\gamma})))u_{m',H}. \quad (\text{A.6})$$

If the solution for  $\mu$  of

$$(1 - e^{-\mu} - \mu e^{-\mu})(v_H - c_H - u_{m'+n-1,H}) = k \quad (\text{A.7})$$

is greater than  $\mu_H(\bar{\gamma})$ , this means that the unconstrained solution for the  $(m'+n)$ -th application (starting from reservation utility  $u_{m'+n-1,H}$ ) is feasible and hence preferred to market  $p_H(\bar{\gamma})$ . Let  $\bar{n}$  be the lowest value of  $n$  for which this happens, that is, at which the  $L$ -type incentive constraint no longer binds. In equilibrium  $H$ -types will then send  $\bar{n} - 1 \geq 0$  applications to wage  $p_H(\bar{\gamma})$ . For all  $n \geq \bar{n}$ , we set  $\mu_{m'+n,H}(\bar{\gamma})$  equal to the unconstrained solution, solving (A.7) for a level of the market utility  $u_{m'+n,H}$  determined by (10), starting from the

value  $u_{m'+\bar{n}-1,H}$  pinned down by (A.6). Set then  $\mu_{m'+n,H}(\bar{\gamma})$  equal to  $\mu_H(\bar{\gamma})$  for  $n = 1, \dots, \bar{n} - 1$  and to the unconstrained solution, solving (A.7), for  $n = \bar{n}, \dots, N - m'$ .

Using these values we can derive the value of the probability with which an  $H$ -type worker is not hired in one of the  $H$ -type markets as a function of the effective composition  $\bar{\gamma}$  in the pooling market:

$$\tau_H(\bar{\gamma}; m') = \prod_{n=1}^{N-m'} (1 - \psi(\mu_{m'+n,H}(\bar{\gamma}))). \quad (\text{A.8})$$

For any given  $m, m' \geq 1$ , the effective composition  $\bar{\gamma}$  in the pooling market is determined by:

$$\bar{\gamma} = \frac{\sigma m}{\sigma m + \tau_H(\bar{\gamma}; m')(1 - \sigma)m'} \quad (\text{A.9})$$

To see that (A.9) has a solution, for any  $m, m'$ , notice that both the left-hand side and the right-hand-side are continuous in  $\bar{\gamma}$  on  $(0, 1)$ .<sup>19</sup> Since  $\tau_H(\bar{\gamma})$  belongs to  $(0, 1)$ , the value of the right-hand side belongs to the interval  $(\frac{\sigma m}{\sigma m + (1 - \sigma)m'}, 1)$ . As  $\bar{\gamma} \rightarrow 0$  the left-hand side is then strictly smaller than the right-hand side, which is always greater than  $\frac{\sigma m}{\sigma m + (1 - \sigma)m'}$ . In contrast, as  $\bar{\gamma} \rightarrow 1$ , the left-hand side is strictly greater than the right-hand side, since for any given  $N, m, m'$ ,  $\lim_{\bar{\gamma} \rightarrow 1} \tau_H(\bar{\gamma}; m') > 0$ . Hence, a solution of (A.9) always exists, constituting a candidate equilibrium for any  $m, m' \geq 1$ .

*No profitable deviations.* We want to show that for  $N > l$ , the candidate equilibrium with the specification  $m = m' = N - l$  exists. Incentive constraints of workers are satisfied by construction. Hence, what we need to show is that firms cannot gain by posting an off-path wage. The following lemma pins down the off-path beliefs regarding the composition of workers in the candidate equilibrium. The proof is in the Online Appendix.

**Lemma 8.** *Consider the candidate equilibrium constructed in Appendix A.3 with  $m = m' = N - l$ . For all  $p \in [0, \bar{p})$  and  $p \in (\bar{p}, p_H)$ , we have  $\gamma(p) = 1$ .*

According to Lemma 8, firms believe to attract the  $L$ -type when posting a wage below  $\bar{p}$ . Single crossing and  $L$ -type's indifference between sending the  $l$ -th application to  $p_{l,L}^*$  and  $\bar{p}$  imply that for any  $p < \bar{p}$ , the pair  $(p, \mu(p))$  belongs to the upper envelope of the indifference curves of the  $L$ -type's first  $l$  applications. This property and  $\gamma(p) = 1$  imply that there is no  $p < \bar{p}$  such that  $\eta(\mu(p))(v_L - p) > k$ .

For wages  $p$  belonging to  $(\bar{p}, p_H)$ , the queue length  $\mu(p)$  is such that

$$(\mu(p), p) \in I_L(u_{N-1,L}, u_{N,L}). \quad (\text{A.10})$$

<sup>19</sup>It is immediate to verify that the map  $\mu_H(\bar{\gamma})$ , defined above, is continuous in  $\bar{\gamma}$ , while for  $n \geq \bar{n}$  the map  $\mu_{m'+n,H}(\bar{\gamma})$  is in fact independent of  $\bar{\gamma}$ .

A sufficient condition for a deviation to such wages not to be profitable is that prices above  $\bar{p}$  are higher than the net productivity of  $L$ -type workers, i.e.,  $\bar{p} \geq v_L - k$ . This condition is satisfied whenever the productivity of  $H$ -type workers is sufficiently high, so that the composition in the mixed market is sufficiently favorable (again, for the construction of an explicit bound for  $v_H$ , see below). In this case, the isoprofit curve  $\Pi_L$  and the indifference curve  $I_L(u_{N-1,L}, u_{N,L})$  have no intersection, so all pairs  $(p, \mu(p)) \in I_L(u_{N-1,L}, u_{N,L})$  yield a negative profit for firms.

Finally, standard arguments imply that firms do not want to deviate to wages  $p > p_H$  (where  $\gamma(p) = 0$ ), as such a deviation would constitute a move away from the unconstrained solution of the problem of attracting  $H$ -types, with reservation utility  $u_{N-l,H}$ .  $\square$

**Bound for  $v_H$ .** We now construct an explicit threshold for  $v_H$  above which the statement of Proposition 3 holds. To this end, we will construct two thresholds, the first assuring that firms cannot attract high types to wages below  $p_{l,L}^*$  without violating any  $L$ -type incentive constraints, the second one assuring that firms cannot profit from attracting low types at wages above  $\bar{p}$  in the candidate equilibrium with partial pooling.

For the first threshold, let us introduce the  $L$ -type's lower contour set in the observable type allocation, i.e. all the pairs  $(\mu, p)$  that the  $L$ -type worker does not prefer to  $(\mu_{n,L}^*, p_{n,L}^*)$  for all  $n \in \mathbb{N}$ :

$$U_L \equiv \{(\mu, p) \geq (\mu_{1,L}^*, p_{1,L}^*) : \forall n \in \mathbb{N}, \psi(\mu) (p - c_L - u_{n-1,L}^*) \leq u_{n,L}^* - u_{n-1,L}^*\}.$$

If the difference between  $v_H$  and  $v_L$  is sufficiently close to or equal to zero, the set  $U_L$  has a non-empty intersection with the  $H$ -type isoprofit curve,  $\Pi_H$ . As  $v_H$  grows, the intersection of the two sets shrinks. Let  $v_H^0$  be then the largest value of  $v_H$  such that  $U_L \cap \Pi_H \neq \emptyset$ . Note that, for  $v_H > v_H^0$ , the only incentive-compatible pairs  $(\mu, p)$  yielding zero profits with the  $H$ -type are the points in  $\Pi_H$  lying above the intersection with  $I_{N,L}$ .

For the second threshold, notice that the probability with which  $H$ -types do not receive an offer in the  $H$ -type markets in the candidate equilibrium with partial pooling is bounded below by  $\tau_H(\sigma, 1)$ , as specified in (A.8), the probability associated to a specification where both types send one application to the pooling market and the composition in that market is given by the population average. For any  $N > l$ , the actual number of applications going to the pooling market is greater than one, while the composition is worse than the population average ( $\bar{\gamma} > \sigma$ ). Both changes tighten the incentive constraint and thus imply a higher probability of  $H$ -types not receiving an offer in one of the  $H$ -type markets. For all  $N > l$ , we thus have  $\tau(\bar{\gamma}, N - l) > \tau(\sigma, 1)$ , with  $\bar{\gamma}$  determined as the fixed point of (A.9). Since  $\tau(\sigma, 1)$  is a lower bound for the probability that  $H$ -types do not receive an offer in the  $H$ -type

markets, the composition parameter associated to  $\tau(\sigma, 1)$ ,

$$\tilde{\gamma} = \frac{\sigma}{\sigma + (1 - \sigma)\tau(\sigma, 1)},$$

constitutes an upper bound for the equilibrium parameter  $\bar{\gamma}$ . Consider then the pair  $(\mu, p)$  satisfying the following equations:

$$u_{i,L}^* - u_{i-1,L}^* = \psi(\mu)(p - c_L - u_{i-1,L}^*), \quad (\text{A.11})$$

$$\eta(\mu)(\tilde{\gamma}v_L + (1 - \tilde{\gamma})v_H - p) = k. \quad (\text{A.12})$$

The (two) solutions of these equations represent the intersections between the  $L$ -type indifference curve associated to the  $l$ -th application in the observable type case and the firms' isoprofit curve associated to markets with effective composition  $\tilde{\gamma}$ . Considering the solution with the higher value of  $p$ , it is immediate to verify that this value is increasing in  $v_H$ . Let value  $v_H^1$  be the value of  $v_H$  such that this solution equals  $p = v_L - k$ . For all  $v_H > v_H^1$ , there can then be no intersection between an indifference curve passing through the point  $(p, \mu)$ , determined by (A.11-A.12), and the isoprofit curve  $\Pi_L$ . Since for any  $N > l$ , the equilibrium parameter  $\bar{\gamma}$  is lower than  $\tilde{\gamma}$  (there are fewer low types), the same property holds for all indifference curves passing through the equilibrium pooling market.

We then set  $\bar{v}_H = \max\{v_H^0, v_H^1\}$ . □

## A.4 Proof of Proposition 6

The argument for the case  $c_H \geq v_L - k$  is in the main text. We thus consider  $c_H < v_L - k$  and  $k \rightarrow 0$ .

**Case  $N = 1$ .** The  $L$ -type's utility in the limit as  $k \rightarrow 0$  is

$$u_{1,L} = v_L - c_L,$$

as can be seen from (9)-(10). The associated indifference curve is

$$I_L(c_L, v_L - k) = \left\{ (p, \mu) : v_L - c_L = \frac{1 - e^{-\mu}}{\mu}(p - c_L) \right\}.$$

The  $H$ -type market in the limit allocation is determined by the intersection of this indifference curve with the vertical isoprofit curve  $p = v_H$ . The  $H$ -types' limit trading probability is thus given by

$$\psi_{1,H} = \frac{v_L - c_L}{v_H - c_L},$$



and their limit market utility is

$$u_H(1) = \frac{(v_L - c_L)(v_H - c_H)}{v_H - c_L}.$$

**Case  $N = 2$ .** Since  $\lim_{k \rightarrow 0} u_{L,1} + c_L = v_L > c_H$ , we have  $l = 1$ . Hence, for  $N = 2$ , there is a partial pooling equilibrium, as described in Proposition 3. Let  $\bar{\gamma}$  be the equilibrium proportion of low types in the mixed market. In the limit as  $k \rightarrow 0$ , the trading probability in the mixed market, denoted by  $\bar{\psi}$ , is determined by the intersection of the  $L$ -type's indifference curve and the vertical isoprofit-curve  $p = \bar{\gamma}v_L + (1 - \bar{\gamma})v_H$ :

$$\bar{\psi} = \frac{v_L - c_L}{\bar{\gamma}v_L + (1 - \bar{\gamma})v_H - c_L}.$$

The associated equilibrium payoff for the  $L$ -type as a function of  $\bar{\gamma}$  is then

$$\begin{aligned} u_{2,L} &= \bar{\psi}(\bar{\gamma}v_L + (1 - \bar{\gamma})v_H - c_L) + (1 - \bar{\psi})(v_L - c_L) \\ &= \left(1 + \frac{(1 - \bar{\gamma})(v_H - v_L)}{(1 - \bar{\gamma})(v_H - v_L) + (v_L - c_L)}\right) (v_L - c_L). \end{aligned}$$

The limit trading probability in the  $H$ -market,  $\psi_{2,H}$ , makes the  $L$ -type indifferent between sending his second application to the mixed market and the  $H$ -market. It is thus determined by

$$\begin{aligned} &\left(1 + \frac{(1 - \bar{\gamma})(v_H - v_L)}{(1 - \bar{\gamma})(v_H - v_L) + (v_L - c_L)}\right) (v_L - c_L) = \psi_{2,H}(v_H - c_L) + (1 - \psi_{2,H})(v_L - c_L) \\ \Leftrightarrow \psi_{2,H} &= \frac{(1 - \bar{\gamma})(v_L - c_L)}{(1 - \bar{\gamma})(v_H - v_L) + v_L - c_L}. \end{aligned}$$

The  $H$ -type's market utility in the limit as  $k \rightarrow 0$  is then

$$u_{2,H} = \psi_{2,H}(v_H - c_H) + (1 - \psi_{2,H})\bar{\psi}(\bar{\gamma}v_L + (1 - \bar{\gamma})v_H - c_H). \quad (\text{A.13})$$

Note that the trading probability in the  $H$ -market,  $\psi_{2,H}$ , is strictly decreasing in the equilibrium composition  $\bar{\gamma}$ . That is, the higher the proportion of low types in the mixed market, the smaller is the probability for high types to trade in the  $H$ -market. The  $H$ -type's market utility is in turn increasing in  $\psi_{2,H}$  and decreasing in  $\bar{\gamma}$ . Hence,  $u_{2,H}$  is strictly decreasing in  $\bar{\gamma}$ .

*Fixed point.* The endogenous composition of the mixed market in the limit as  $k \rightarrow 0$  is

determined by the equations

$$\begin{aligned}\bar{\gamma} &= \frac{\sigma}{\sigma + (1 - \sigma)(1 - \psi_{2,H})}, \\ \psi_{2,H} &= \frac{(1 - \bar{\gamma})(v_L - c_L)}{(1 - \bar{\gamma})(v_H - v_L) + v_L - c_L}.\end{aligned}$$

The first equation can be written as

$$\bar{\gamma}\sigma + \bar{\gamma}(1 - \sigma)(1 - \psi_{2,H}) = \sigma \quad \Leftrightarrow \quad \frac{\bar{\gamma}}{1 - \bar{\gamma}}(1 - \psi_{2,H}) = \frac{\sigma}{1 - \sigma}.$$

Consider now an increase in  $\sigma$ . This strictly increases the RHS of the last equation, hence the LHS must increase as well. Recalling that  $\psi_{2,H}$  is strictly decreasing in  $\bar{\gamma}$  (so  $1 - \psi_{2,H}$  is strictly increasing), this requires that  $\bar{\gamma}$  increases. Hence, the composition of the mixed market  $\bar{\gamma}$  strictly increases in the population parameter  $\sigma$  with the following limits.

- As  $\sigma \rightarrow 1$ ,  $\bar{\gamma} \rightarrow 1$ ,  $\bar{\psi} \rightarrow 1$  and  $\psi_{2,H} \rightarrow 0$ .
- As  $\sigma \rightarrow 0$ ,  $\bar{\gamma} \rightarrow 0$  and  $\bar{\psi}, \psi_{2,H} \rightarrow \frac{v_L - c_L}{v_H - c_L} = \psi_{1,H}$ .

We denote by  $u_H(2)$  the limit market utility (A.13) with  $\bar{\gamma}$  and  $\psi_{2,H}$  as the fixed point of the equations above.

*Welfare comparison.* Having established the limit allocation for  $k \rightarrow 0$ , we want to argue that for any  $k$  sufficiently small, there is a threshold for  $\bar{\sigma}_k$  such that  $u_H(1) < u_H(2)$  if  $\sigma < \bar{\sigma}_k$  and  $u_H(1) > u_H(2)$  if  $\sigma > \bar{\sigma}_k$ . We know that the market utility  $u_H(1)$  is independent of  $\sigma$  and already showed that, in the limit case  $k \rightarrow 0$ ,  $u_H(2)$  is strictly decreasing in  $\bar{\gamma}$ , which in turn is strictly increasing in  $\sigma$ . Hence, the limit market utility  $u_{2,H}$  is strictly decreasing in  $\sigma$ . We thus have a threshold  $\bar{\sigma} \in [0, 1]$  such that the limit values of  $H$ -types' market utilities satisfy  $u_H(1) < u_H(2)$  if  $\sigma < \bar{\sigma}$  and  $u_H(1) > u_H(2)$  if  $\sigma > \bar{\sigma}$ . What remains to be shown is that this threshold lies on the interior of the unit interval. This follows from

$$\begin{aligned}\lim_{\sigma \rightarrow 0} (u_H(2) - u_H(1)) &= (1 - (1 - \psi_{1,H})^2)(v_H - c_H) - \psi_{1,H}(v_H - c_H) \\ &= \psi_{1,H}(1 - \psi_{1,H})(v_H - c_H) > 0,\end{aligned}$$

and

$$\begin{aligned}\lim_{\sigma \rightarrow 1} (u_H(2) - u_H(1)) &= (v_L - c_H) - \frac{(v_L - c_L)(v_H - c_H)}{v_H - c_L} \\ &= -\frac{(v_H - v_L)(c_H - c_L)}{v_H - c_L} < 0.\end{aligned}$$

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