Referral Hiring and Wage Formation in a Market with Adverse Selection☆

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Abstract

The widespread use of employee referrals raises questions regarding how they affect labor market outcomes. Does referral hiring lead to a more efficient allocation of workers compared to when hiring is possible only on a competitive market? To utilize the social links of their employees, are employers willing to pay a wage premium? We present a game-theoretic model and provide results from a laboratory experiment to address these questions. In line with the theoretical predictions, employers often hire via employee referrals, which in turn mitigates adverse selection and elevates wages. Importantly, employers anticipate the future value of hiring high-productivity employees—which consists of gaining access to valuable social links—and are thus willing to take the risk of offering wage premiums when hiring on the competitive market. We also find that employers' risk aversion and the dynamic nature of the hiring process can help account for the inefficiency remaining in the labor market.

Key words: Adverse Selection, Wage Formation, Asymmetric Information, Referral Hiring, Social Links

JEL Classification: C92, D82, D85, E20

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1. Introduction

Information asymmetries are a persistent source of inefficiency and have been studied extensively in economics since Kenneth Arrow's (1963) and George Akerlof's (1970) seminal works. The premise is that the qualities of goods and services traded in a market are unobservable, which can lead to adverse selection. Labor markets are a prominent example. There, adverse selection leads to a low equilibrium market wage and an inefficient assignment of workers to jobs. However, firms would be willing to pay high wages if they could identify productive workers, which would be optimal for firms and society.[1] Thus, it is important to find mechanisms that can help mitigate inefficiencies in labor markets induced by asymmetric information.

Employee referrals—programs where companies take into account recommendations by current or former employees when filling job openings—have been suggested as one such mechanism through which employers can ensure better social and economic outcomes (e.g., Granovetter, 1985, 1995; Rees, 1966; Fernandez and Moore, 2000). Empirically it has been shown that workers that are part of the same social network may monitor and help each other more effectively (Kugler, 2003; Castilla, 2005; Heath, 2018). It has also been observed that referred employees benefit firms through lower turnover (Weller et al., 2009), in some instances, superior performance (Castilla, 2005; Hensvik and Skans, 2016; Barr et al., 2019), and that they earn higher wages (Burks et al., 2015; Brown et al., 2016). Finally, and most importantly for us, recent studies suggest that employee referrals convey information about the quality of the referred workers (Yakubovich and Lup, 2006; Schmutte, 2014; Burks et al., 2015; Dustmann et al., 2015; Pallais and Sands, 2016), though this information may be noisy (Fafchamps and Moradi, 2015). Despite this evidence, a number of important questions remain open, specifically regarding the impact of employee referrals on aggregate market performance and the causality of the observed effects.

In this study, we use a laboratory experiment to causally identify how employee referrals, through the use of current employees' social links, can alleviate informational asymmetry in a labor market with adverse selection.[2] We contribute to the literature in two ways. First, due to the large scale of many markets, in the field it is usually infeasible to detect the impact of employee referrals on aggregate market performance. Therefore, important previous empirical studies focus on firm-specific outcomes (e.g. Burks et al., 2015; Hensvik and Skans, 2016) or examine how job referrals impact behavior of referrers and the referred (e.g., Beaman and Magruder, 2012; Obukhova and Lan, 2013; Pieper et al., 2019). In contrast, in the laboratory environment crucial variables are observable to the researcher, which admits an analysis of how employee

[1] Greenwald (1986) has shown that adverse selection of workers extends further to the stream of job changers, because firms tend to concentrate on preventing turnover on their better workers.

[2] For a critical view on the ecological validity of laboratory experiments, see Levitt and List (2007). Studies demonstrating that behavior in the laboratory has predictive value for field behavior include Falk et al. (2013), Cooper and Kagel (2016), Riedl and Smeets (2017), and Snowberg and Yariv (2021). A more detailed discussion on this issue can be found in Section 5.

referrals affect *aggregate* market dynamics, market efficiency, and the formation of market wages. In that regard, one key result we offer is that the availability of hiring through referrals results in a wage premium even on the competitive and public market, where employees are hired via posted offers. In particular, employees can benefit from the availability of referral hiring even when they are not themselves hired through a referral, because employers raise wages to obtain access to higher-quality social links (in line with Montgomery, 1991a).

Second, it is generally accepted that employee referrals serve a central function in the hiring process. For instance, about one half of all open positions in the U.S. and European labor market are allocated through referrals by friends and relatives (e.g., Ioannides and Loury, 2004; Jackson, 2010a; Pellizzari, 2010; Topa, 2011).[3] However, this could be due to a multitude of factors, including the informational value of referrals, but also faster and cheaper job-matching (Calvó-Armengol and Zenou, 2005; Obukhova and Lan, 2013; Galenianos, 2014) or benefits derived from long-term employee attachment to the firm (Castilla, 2005; Pieper et al., 2019). In the field it is difficult to distinguish between these factors and identify causal effects of job referrals, because social links are endogenous and the productivity of employees is difficult to quantify. In some cases, employee referrals may also have unintended consequences such as job segregation (e.g., Rubineau and Fernandez, 2013) and increased inequality (e.g., Calvo-Armengol and Jackson, 2004; Galenianos, 2020) that can affect behavior in unpredictable ways. We leverage the laboratory environment to identify the impact of the *informational* value of employee referrals, abstracting from other effects that social networks may have in labor markets.

A central premise of our approach is that workers have social links and that there is a positive correlation in productivity between workers in the same social network. This assumption is supported by studies showing that people tend to interact with others that are similar to themselves, often referred to as homophily. In our setting, we think of homophily as implying a correlation in productivity among employees with a social link (e.g., Fernandez and Moore, 2000; McPherson et al., 2001; Currarini et al., 2009; Jackson, 2010b; Zeltzer, 2020). We, thus, take the correlation in productivity as given and focus on its consequences for aggregate market outcomes, in a setting where efficiency is hindered by substantial information asymmetry about individual productivity.

Our experimental environment corresponds to a standard labor market setting with asymmetric information. The main novelty is that we exogenously vary the availability of employee referrals, and hence information that can be accessed through social links. The hiring process takes place in an anonymous public market where employers can post offers and workers choose if and when to accept. The number of workers exceeds

[3]Employee referrals are also widely used in developing countries (Heath, 2018), in migrant communities (Munshi, 2003; Beaman, 2011), and are pervasive in different industries ranging from call-centers to high-tech firms (Burks et al., 2015).

the number of available jobs. However, workers may nevertheless extract part of the surplus, because they are privately informed about their productivity, which can be low or high. The hiring process takes place in two stages and employers seek to hire one worker per stage. The profit of an employer depends on the productivity of the hired workers and the wage the employer pays to these workers. The earnings of the workers are determined by the wage they receive or, if a worker fails to find a job, by his or her outside option. An outside option could reflect a worker's benefit from waiting for new job openings or from being hired in a different industry. High-productivity workers are assumed to have better outside options than low-productivity workers.

We implement two treatments. In the *Baseline* treatment, there are no social links between workers in stage 1 and stage 2. Hence, knowledge about the productivity of a stage-1 worker does not contain information regarding the productivity of a stage-2 worker. In this treatment, stage 1 and stage 2 can be thought of as two independent markets characterized by the same incentives. In contrast, in the *Referral* treatment, each stage-1 worker has a social link with a stage-2 worker, meaning that the linked workers are of the same productivity type with a high probability. Thus, in this treatment the productivity of a stage-1 worker is informative about the productivity of the stage-2 worker linked to the hired stage-1 worker. Employers can utilize this information by making referral offers to the stage-2 worker. The hiring decisions employers make in stage 1 thus directly affect their hiring opportunities in stage 2. Importantly, referral offers do not give exclusive access to a worker: all stage-2 workers can also be hired on the public market.

We develop a theoretical model to derive testable hypotheses for the experiment. The model builds on a well-established theoretical literature on social networks in labor markets and job-search through personal contacts (e.g., Greenwald, 1986; Montgomery, 1991a; Mortensen and Vishwanath, 1994; Pissarides, 2000; Topa, 2001; Kugler, 2003; Obukhova and Lan, 2013; Rubineau and Fernandez, 2013; Galenianos, 2014).[4] However, existing models typically assume free entry by firms (i.e., the number of firms is endogenous and firms make zero profits), allow for rich and complicated network structures, assume risk neutrality, and look at behavior in the steady state of a market. These features are difficult to implement experimentally. Our model lends itself to an experimental implementation while retaining central predictions of the previous theoretical literature. Most crucially, it predicts the alleviation of adverse selection due to the availability of referral hiring and a potential increase in inequality between low and high-productivity workers.

We derive the following testable predictions. First, our model predicts that wage

[4]The theoretical literature on social networks in labor markets examines a broad range of other important issues such as the impact of network structure on labor market outcomes (e.g. Boorman, 1975; Zenou, 2013), how network connections provide information about available jobs (e.g., Calvó-Armengol, 2004; Galeotti and Merlino, 2014), job tenure (e.g. Loury, 2006), career concerns (Ekinci, 2016), and how social networks may induce inequality (e.g. Montgomery, 1991b; Calvo-Armengol and Jackson, 2004; Galenianos, 2020).

offers in the public market are higher when employee referrals are possible (*Referral* treatment) than in the absence of social links (treatment *Baseline*). Specifically, it predicts a higher frequency of wage offers that match the reservation wage of high productivity workers, because this increases the likelihood of hiring a high-productivity worker. Employers anticipate that hiring a high-productivity worker will grant access to a better social network from which they can draw workers in the subsequent hiring round. Second, if employers succeed in hiring a high-productivity worker in stage 1, they should make use of referral wage offers in stage 2, and workers receiving such offers should accept. This is because the expected productivity of such referral workers is higher than the productivity of the average worker on the market. Third, these predictions imply that the availability of employee referrals should increase market efficiency. This effect results from a displacement of low-productivity hires by high-productivity hires, compared with the setting without social links. Consequently, as employee referrals are not predicted to increase the overall number of hires, referrals tend to increase inequality among workers.[5]

While these predictions are intuitive, the equilibrium strategies involve mixing and the market equilibrium is characterized by non-trivial trade-offs. Employers trade off the benefits from hiring high-productivity stage-1 workers—i.e., higher expected profits through access to workers' social links—with the risk of hiring a low-productivity stage-1 worker at a high wage. Whether offering high wages is a profitable strategy depends on an employer's expectation about the willingness of low-productivity workers to accept lower wages and on the degree of risk aversion present on both market sides. Workers, on the other hand, trade off the time they wait before accepting a wage offer with the risk of remaining unemployed. Thus, even if social links are by design informative about productivity, whether the presence of employee referrals alleviates adverse selection is uncertain, as it depends among others on the market participants' expectations, and hence needs empirical validation.

Our empirical results largely support the hypotheses derived from the theoretical model, demonstrating the value of employee referrals in alleviating inefficiencies caused by the asymmetric information present in the market. Specifically, we find that, (*i*) the allocation of workers to employers is significantly more efficient in the *Referral* treatment than in the *Baseline* treatment, (*ii*) hiring through social links is common and mostly concerns high-productivity workers, and (*iii*) employers appear to anticipate this and offer in stage 1 more frequently wages that meet the high productivity workers reservation wage in the *Referral* treatment than in the *Baseline* treatment, the

[5]In our model there are no search frictions. Specifically, as in Montgomery (1991a) or Wilson (1980), workers can observe the public wage offers of all employers. Introducing search frictions (e.g., as in Siegenthaler, 2017) would add another channel through which employee referrals potentially improve market efficiency, though baseline efficiency would be lowered due to the search frictions. Interestingly, it is likely that this would further exacerbate the increase in inequality due to referral hiring, as workers with a social link to high-productivity workers would benefit not only from the reduction in uncertainty about productivity but also from lower search costs.

aforementioned risks notwithstanding. Interestingly, the positive effect of social links is partly based on low-productivity workers underestimating the probability of being hired when holding out for high wages.

Despite the positive effect of employee referrals on efficiency, we observe that it falls short of the second-best efficient outcome, which is defined as the maximum welfare subjects can obtain given the constraint that social links are not fully informative. We show that the failure to reach second-best efficiency is caused by a combination of risk aversion on both sides of the market and the dynamics of the hiring process. Employers almost always start with low wage offers, leading to many early low-productivity hires. The more risky, and socially more efficient, strategy of offering higher wages is adopted only late during market opening time. This suggests that employee referrals are important for mitigating adverse selection in labor markets, but that other mechanisms are needed to further improve efficiency. In that regard, our study contributes to the growing experimental literature testing mechanism to alleviate informational inefficiencies in competitive markets (reviewed in the conclusion).

The main contribution of our study is to show that the availability of referral hiring causally mitigates informational hurdles in a labor market (e.g., Stigler, 1962; Pieper et al., 2018). Specifically, the laboratory experiment allows us to analyze aggregate market dynamics and wage formation, and to observe counterfactual behavior in the absence of referral hiring. Another noteworthy insight is that referral hiring is especially important in the presence of risk aversion, as risk averse firms offer wages that are too low for the market to operate efficiently. That risk aversion affects firms' decision-making has been argued for also by Kahneman and Lovallo (1993), who write that "the forces that produce risk aversion in experimental studies of individual choice may be even stronger in the managerial context." A growing literature agrees with this view and reports that risk aversion plays a central role also for firms (e.g., Maccrimmon and Wehrung, 1986; Frank, 1990; Choudhary and Levine, 2010; Baert, 2018; Lovallo et al., 2020).

Moreover, our results are the first to show empirically that offering better wages on the public (non-referral) market provides improved access to valuable social links for subsequent hiring. Therefore, firms can increase their performance by ensuring, already at the hiring stage, that wage offers in the public market reflect a worker's expected productivity *plus* the "option value" of her referral network (Montgomery, 1991a). This insight complements Pieper et al. (2018) who show that, because referrals can be risky for the employee to make, firms often offer bonuses to their employees for successful referral hiring.

Finally, we believe that our findings are relevant beyond the labor market context. Specifically, self-employed doctors, realtors, or gig workers—such as drivers, caregivers, freelance programmers, and housekeepers—are often hired through the social links of their current clients (e.g., Jackson, 2010b). Replacing the term "firm" by "consumer" and the term "worker" by "service provider", our findings are applicable to these examples as well. Indeed, it is difficult to imagine that the markets for many of the above examples would function without the information consumers obtain through referrals, given the extent of risk aversion consumers exhibit in such settings.[6]

The paper proceeds as follows. In Section 2, we present the experimental setting and design. Section 3 introduces the theoretical model and derives three key hypotheses for behavior in the experiment. In Section 4, we present the empirical results and Section 5 concludes.

2. Design of the Experiment

Our experimental environment is designed to reflect a typical labor market setting with adverse selection. Specifically, the existence of asymmetric information implies that it is risky for employers to offer wages that are acceptable to high-productivity workers because they may end up paying a high wage to low-productive workers. Our treatments exogenously vary the availability of employee referrals and are described in more detail below. First, we present the general setting that applies to both treatments.

2.1. General Setting

In each session of the experiment there are 16 participants. At the beginning of a session, the market participants are randomly assigned the role of either a firm or a worker. For clarity, the lab experiment was framed as a labor market in which firms can hire workers. In line with this, in the following we will use the terms firm and worker. In total there are 4 firms and 12 workers that interact in a market. The roles remain fixed throughout a session and each session consists of 15 periods, which should give participants enough time to experiment with different strategies and converge to what in their view constitutes optimal behavior. Each period constitutes a distinct market and the number of firms and workers is the same in all markets. All periods were paid.

In each period, subjects interact in a market with two hiring stages. A stage lasts for 2 minutes during which firms seek to hire at most one worker, by posting wage offers. Firms are free when or how many offers they would like to make and workers can accept any of the standing offers at any time. Firms are active in both stages whereas the 12 workers are divided into 6 stage-1 workers and 6 stage-2 workers. Stage-1 workers are active only in stage-1 and thus can only be hired in this stage; equivalently for stage-2 workers. Whether a worker is active in stage 1 or stage 2 is randomly determined at the beginning of each period.

When making offers, firms have to abide by the improvement rule. That is, every new wage offer has to be higher than the currently highest standing wage offer. When there are no standing offers (which occurs at the beginning of a hiring stage or when all

[6] These examples are distinct from markets such as Airbnb and ride-sharing that rely on public reviews. While both public reviews and referrals reduce information asymmetries, public reviews are broadly accessible and require a narrow definition of quality, e.g., the cleanliness of an apartment. Referrals, on the other hand, are accessible only through social networks but are significantly more informative even for qualities that are difficult to measure such as an employee's productivity.

standing offers have been accepted), new offers can again start at the lowest permissible wage. This is a standard rule in experimental markets (e.g., Smith, 1962; Fehr et al., 1993, 1998; Fehr and Falk, 1999) and rules out the possibility that firms make offers that should never be accepted by workers.

To implement asymmetric information, workers are further divided into low-productivity (L-type) workers and high-productivity (H-type) workers. Specifically, in each hiring stage there are 3 L-type and 3 H-type workers. The productivity of a worker is randomly determined at the beginning of each period. Importantly, firms know the distribution of worker types but are informed about their worker's actual productivity only after the worker has been hired.

Firms' profits in a stage are determined as follows. A low-productivity worker produces an output $P_L = 20$ and a high-productivity worker produces an output of $P_H = 60$. The set of permissible wage offers is $\{0, 1, \ldots, 59, 60\}$. If a firm pays a wage w, her payoff in a given stage is given by

$$\pi_F(\theta, w) = \begin{cases} 20 + P_\theta - w & \text{if a worker of type } \theta = \{L, H\} \text{ is hired} \\ 0 & \text{if no worker is hired.} \end{cases} \tag{1}$$

Adding the extra payoff of 20 reduces the risk of negative payoffs in the experiment and guarantees firms positive payoffs when hiring an L-type worker at the H-type workers' reservation wage (see below). As will be shown in the next section, equilibrium market wages are below the H-type workers' reservation wage with positive probability, which gives rise to adverse selection. In a period, the total payoff of a firm is the sum of payoffs in stage 1 and stage 2.

Workers' payoffs are determined by the wage when hired and their outside option when not hired. It is assumed that workers of different productivity types have different outside options and, thus, different reservation wages. Specifically, an L-type worker has a reservation wage of $\lambda_L = 10$ and an H-type worker has a reservation wage of $\lambda_H = 30$. In a stage, the payoff of a worker is given by

$$\pi_W(\theta, w) = \begin{cases} w & \text{if hired} \\ \lambda_\theta & \text{if not hired and of type } \theta = \{L, H\}. \end{cases} \tag{2}$$

The different reservation wages imply that it is risky for firms to try to hire high-productivity workers. Hiring such workers requires a wage offer of at least 30, which entails the risk of a low payoff in case a low-productivity worker accepts the offer.

Workers are active either in stage 1 or stage 2, whereas firms are active in both stages. Workers receive their reservation wage also in the stage in which they are not active. This is in line with the interpretation that the reservation wage corresponds to a worker's utility when not hired (outside option). Another benefit of paying workers in both stages is that, like firms, workers accumulate earnings in both stages. The earnings of firms and workers thus, approximately, remain similar over the course of the experiment, thereby avoiding unintended effects due to social preferences.

2.2. Treatments

There are two treatments that differ in the possibility of hiring workers via referrals. In the *Baseline* treatment, the productivity of stage-1 and stage-2 workers is unrelated. In both hiring stages, firms make wage offers in an anonymous public posted-offer market. We will refer to such offers as *public offers*. All firms and all workers active in a stage can observe all public offers. Workers not active in a stage do not observe any offers. A worker that accepts an offer is hired at the corresponding wage by the firm which made the offer, and this worker-firm pair leaves the market. The remaining workers can still get hired by the other firms on the market. In both stages, the market is open for at most 2 minutes or until all firms have hired a worker.

The *Referral* treatment differs from *Baseline* in the availability of employee referrals. In particular, social links connect the productivity of stage-1 workers to the productivity of stage-2 workers, such that two linked workers are of the same type with a probability of 75%. We thus model social links as a correlation in productivity, abstracting from other potential impacts of social networks in labor markets such as mutual monitoring and reduced turnover. Social links are randomly assigned among workers at the beginning of each trading period and each stage-1 worker is uniquely linked to one stage-2 worker. The first stage of the *Referral* treatment is exactly the same as in the *Baseline* treatment and all hires take place via public offers. However, social links affect the hiring opportunities of firms in the stage-2 market.

Specifically, in stage 2, firms can make two types of offers. First, they can make public offers which are observed by all firms and all stage-2 workers. Second, each firm that has hired a worker in stage 1, can try to hire a worker through an offer that is only received and observed by the stage-2 worker that has a social link with that firm's stage-1 worker. We will refer to such offers as *referral offers*.[7] Firms can make multiple offers of both types (public and referral) simultaneously during the 2 minutes the stage-2 market is open.[8] Importantly, workers that receive referral offers can still accept wage offers in the public market. Thus, unless all firms only make referral offers, the firms still compete for workers. Referral offers have the advantage that, due to the social link, there is less noisy information regarding the stage-2 worker's productivity.

2.3. Information

In both treatments, participants are informed about all relevant parameters of the experiment. That is, they know that there are (a) 15 periods with two trading stages

[7] Referral offers can be changed in any way. As explained above, the improvement rule prevents firms from making non-competitive offers in the public market, and thus helps organize the market. This is not an issue for referral offers, because each worker observes at most one referral offer. We therefore do not impose the improvement rule for referral offers.

[8] In the experiment, this was implemented via two panels showing standing offers that firms and workers could observe. In one panel, firms could make public offers and all workers could accept. In the other panel, firms could make referral offers to their linked stage-2 worker. Since each such worker is linked to exactly one firm, a given worker could only observe the referral offers of this one firm. A screen shot of the experimental interface can be found in the online appendix.

in each period, (b) 4 firms and 6 workers per trading stage, (c) 3 low- and 3 high-productivity types among the 6 workers, and they also know (d) the payoff functions of both firms and workers. In the *Referral* treatment, participants know from the start of the experiment that stage-1 and stage-2 workers that are connected by a social link are of the same productivity type with a probability of 75%. Finally, firms and workers active in a stage can observe all public offers made in that stage. In contrast, referral offers can only be seen by the worker that receives the offer.[9]

2.4. Procedures

The experiment was run in 2011 at the BEElab of Maastricht University, using experiment software z-Tree (Fischbacher, 2007) and participants were recruited from the BEElab participant pool via ORSEE (Greiner, 2015). In total 176 participants were active in the two treatments, *Baseline* and *Referral*. In each treatment 16 participants (4 firms and 12 workers) formed an independent group, with five in *Baseline* and six in *Referral*.[10] At the beginning of a session each participant was randomly assigned to a cubicle where they made decisions in private. The experiment instructions included a set of comprehension questions to check participants' understanding. The instructions can be found in Online Appendix D. Each session lasted 100 minutes or less and payments averaged 19 Euros per participant including a show up fee of 5 Euros.[11]

3. Theoretical Background

We present a model to derive a set of hypotheses for behavior in the experiment. Our model is inspired by Montgomery (1991a) as well as Wilson (1980). Specifically, we follow Montgomery (1991a) by exploring a two-stage labor market in which workers can be of two types, low and high productivity, and are active for one stage. A social structure is introduced by assuming that each stage-1 worker has a social link to a stage-2 worker, and there is a positive correlation in the productivity of two linked workers. Firms can hire at most one worker per stage. Workers are observationally

[9]The design element that referral offers can not be seen by other firms follows Greenwald (1986) who argues that for firms it is difficult to observe wage offers that workers receive from their current employer; for instance, because wage offers from current employers can involve credible future promises and because current employers can often directly respond to outside offers. Similar arguments apply to referral offers. In the concluding section of the article, we discuss how markets would be affected if referral offers were publicly observable.

[10]As common for market experiments, the number of participants in an independent group is rather high (16 in our case) leading to a number of strictly independent observations that may be viewed as being on the low side for detecting significant effects. To minimize the chance of false positives, we use a rather conservative statistical approach (see Section 4, Footnote 16).

[11]Typical for adverse selection settings, in our experiment it is possible that participants receive negative payoffs. This could be problematic if a participant goes bankrupt, which most likely happens in early periods when participants have not yet accumulated earnings. To deal with this potential issue, participants received an initial endowment of 120 experimental points (conversion rate: 1 point = 2.25 Euro cent). No participant went bankrupt.

equivalent and unable to signal their productivity to potential employers (see also Greenwald, 1986).

Our experimental environment is dynamic and offered wages can change over time. Models of adverse selection that assume that each seller can trade only at a single offered wage (e.g., Akerlof, 1970; Montgomery, 1991a) do not capture this possibility. We therefore follow Wilson (1980) and allow firms to offer multiple wages at which they are willing to hire a worker. If there is excess supply of labor at some wage, hires at that wage are distributed at random.

3.1. Model

Consider a market with n_F firms, n_L low-productivity workers and n_H high-productivity workers. Workers' types are private information. Using the notation introduced in Section 2.1, the productivity of a worker of type θ is P_θ and the reservation wage is λ_θ. We assume $P_H - \lambda_H > P_L - \lambda_L$, i.e., the gains from trade are larger with H-type workers. We also assume $n_L + n_H \geq n_F > n_L$, as in the experiment. This is the most realistic and interesting case, as both market sides can extract part of the surplus and in equilibrium multiple wages can occur. If $n_F \leq n_L$ firms would be essentially monopsonists and (trivially) offer either λ_L or λ_H. If $n_F > n_L + n_H$, there would be a single market wage equal to the expected worker productivity and the expected profit of a firm would be equal to zero.

There are two stages and each firm can hire at most one worker per stage. In each stage, the market opens with firms announcing a finite number of wages. Workers then choose the wage offers they would like to accept. A worker can accept none, one, or several of the offers made by the firms. Given these decisions, firms and workers are then matched from low to high wages. That is, market clearing starts at the lowest accepted wage offer, say w_1, in line with the wage improvement rule implemented in the experiment (see also Kranton and Minehart, 2001). Among the workers that chose to accept w_1, one is hired at random. Then, the next highest accepted wage offer w_2 is selected resulting in another firm-worker match. This process continues until all firms hired a worker or the highest accepted wage offer is reached.

Importantly, wage clearing from below does not require firms to offer low wages—indeed, we will see that in equilibrium some firms post a single wage offer equal to the productivity level of the high-type worker. However, the fact that markets clear from below implicitly also allows for dynamic hiring. To see this, consider a firm that chooses to make two offers, a low offer and a high offer. The firm will first compete for the pool of workers that are willing to accept the low offer and, if the firm is not able to hire such a worker, it can subsequently compete for the remaining workers that demand higher offers. This strategy pattern indeed occurs in equilibrium.[12]

[12]The purpose of the theoretical model is not to provide a one-to-one correspondence to the experimental trading environment. Such a model—featuring continuous-time, multilateral bargaining under incomplete information—would be complicated and, as expectations would play a role, likely feature multiplicity of equilibria. Instead the goal is to account for the central features of the experimental

The key prediction of the model—that employee referrals increase market efficiency—holds for most risk attitudes. The only situation in which referrals do not affect efficiency (because they are not used) is when the informativeness of referrals is very low relative to agents' risk aversion. However, the empirical results will demonstrate that risk aversion plays an important role in accounting for the frequent use of referral offers as well as for the observed market dynamics more generally. We will therefore include a discussion of risk aversion in the equilibrium analysis provided in the next section. To that end, we assume that an agent's utility is given by

$$u(\pi) = 1 - e^{-\sigma\pi}, \tag{3}$$

where π represents the payoffs defined in (1) and (2), respectively, and $\sigma > 0$ measures the degree of constant absolute risk aversion (CARA).

3.2. Market Equilibrium in the Baseline Setting

A *market equilibrium* is reached if firms' wage offers and workers acceptance decisions maximize their respective expected utilities, given the behavior of all firms and workers, and firms' beliefs about the expected quality of workers are correct at all wage levels.[13] In the following, we focus on the key predictions and refer to the appendix for a detailed analysis.

Recall that in the *Baseline* treatment stages 1 and 2 are identical, because there are no social links. The equilibria in each stage take the following form. Firms randomize between posting the H-type reservation wage $\{\lambda_H\}$ or the set of wages $\{w^*, \lambda_H\}$, where $\lambda_L < w^* < \lambda_H$ and the randomization probabilities depend on risk aversion. The trade-off between $\{\lambda_H\}$ and $\{w^*, \lambda_H\}$ is apparent: hiring an H-type worker at a wage of λ_H generates large gains from trade but involves the risk of hiring an L-type worker, in which case the wage w^* would have been preferable. In equilibrium, H-type workers only accept high wages and L-type workers accept both wages w^* and λ_H. The reason the latter accept w^* is that at a wage of λ_H they face competition from H-type workers and, thus, some workers will remain unemployed. It is thus always optimal for a firm that offers w^* to also include offer λ_H in its wage schedule: because w^* is accepted by L-type workers and market clearing occurs from low to high wages, in equilibrium a firm that offers $\{w^*, \lambda_H\}$ will hire at a wage of λ_H only if all L-type workers have already left the market.

Figure 1 provides an illustration of the market equilibrium for different levels of agents' risk aversion. The figure is based on the parameters in the experiment but the qualitative predictions are robust to variations in these parameters. Figure 1(a) shows the average accepted offer and Figure 1(b) shows the percentage of high-productivity

market, specifically the social structure and multiple wage offers per firm. In Online Appendix A, we also discuss the Walrasian equilibrium outcome.

[13] Beliefs are required to be correct also at wages that are not offered in equilibrium. That is, we are interested in equilibrium outcomes that are robust to firms and workers experimenting with different off-equilibrium strategies (see Wilson, 1980; Mas-Colell et al., 1995).

workers among all hired workers, where the total number of hires is four (in equilibrium each firm hires a worker). The solid lines depict the predictions for treatment *Baseline*. Notice that for low levels of risk aversion the equilibrium wage equals $\lambda_H = 30$ and the percentage of hired H-type workers is 50%. All six workers accept a wage of 30 and on average two workers of each productivity type are hired. As agents become more risk averse, firms start to randomize between $\{w^*, \lambda_H\}$ and $\{\lambda_H\}$, which depresses the average wage level. Two effects are at play: first, firms become more reluctant to make high offers and second, L-type workers' willingness to accept low wages increases. The latter happens because the risk of not getting hired plays a larger role in L-type workers' utility calculations. As a result, the percentage of hired H-type workers falls towards 25% for higher levels of risk aversion implying a strong adverse selection effect and ex-post social welfare loss. From a social welfare perspective, all (three) H-type workers should be hired, as the gains from trade with an H-type equal 30 whereas for an L-type they are only 10.

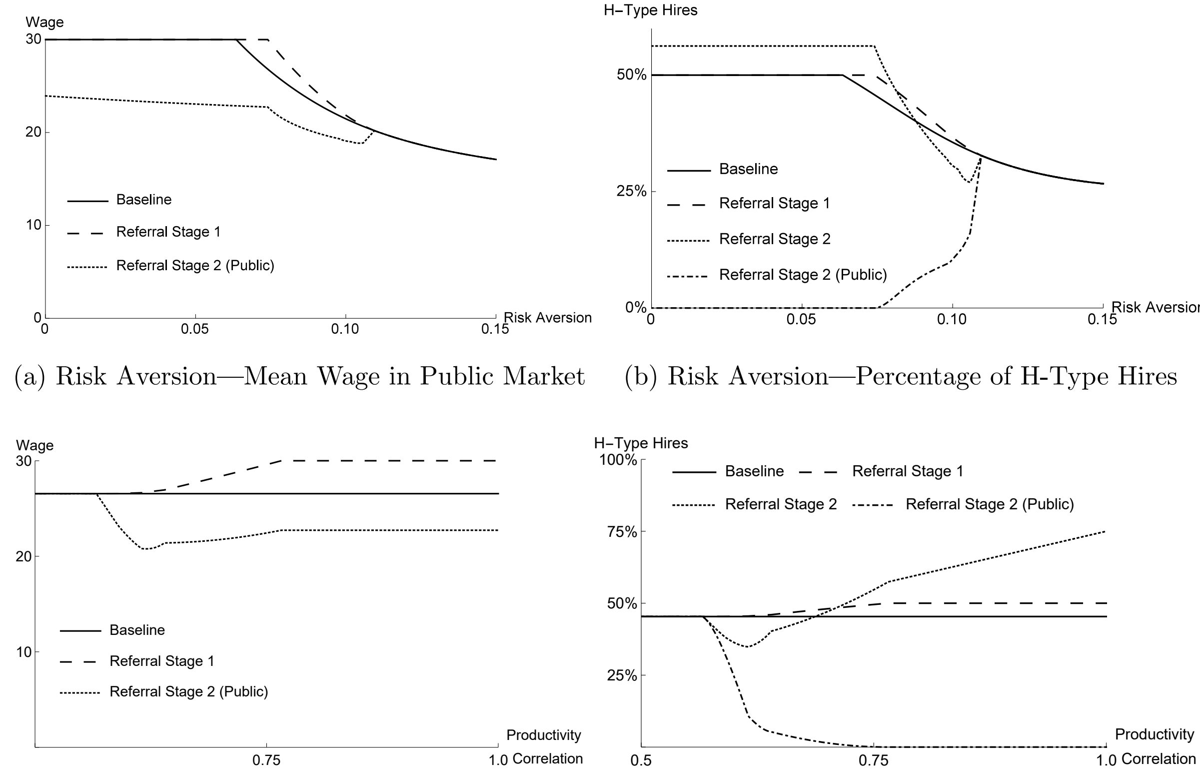
3.3. Market Equilibrium with Referral Offers

We next discuss whether the opportunity to make referral offers alleviates adverse selection. In stage 1 of the *Referral* treatment, the hiring process happens on a public market, as in the *Baseline* treatment. In stage 2, firms can still hire through public offers but, importantly, they can also hire through referral offers using the social links of the hired stage-1 worker. Recall, that with a probability of 75% the linked stage-2 worker is of the same productivity type as the stage-1 worker.

The dashed lines in Figure 1 depict the equilibrium outcomes in stage 1 of the *Referral* treatment, while the dotted lines pertain to stage 2 of the *Referral* treatment. Panels (a) and (b) explore varying degrees of risk aversion. Panels (c) and (d) explore the informativeness of social links, which is measured by the probability, α, that two linked workers are of the same productivity type.

As can be seen in Figure 1(a), for intermediate levels of risk aversion, average wages in stage 1 are higher in the *Referral* treatment than in the *Baseline* treatment. The average wage is higher, because in equilibrium firms are more likely to offer H-type workers' reservation wage $\lambda = 30$. The reason that firms are willing to make these higher wage offers in *Referral* is that this increases their probability of hiring an H-type worker, which—compared to *Baseline*—has the additional benefit of providing access to a social link that can be utilized in stage 2. Specifically, the firm will be able to hire a H-type worker in stage 2 with a probability of 75% through a referral offer. As a result, in *Referral* more H-type workers are hired in stage 1, compared to *Baseline* (see Figure 1(b)).

The dotted line in Figure 1(b) shows that the percentage of H-type hires in stage 2 is higher in the *Referral* treatment than in the *Baseline* treatment (solid line) as long as the degree of risk aversion is not too large. The logic behind this is that in stage 2 of the *Referral* treatment, up to a risk coefficient of about 0.1, firms that have hired an H-type worker in stage 1 always make referral offers of 30 in stage 2. For higher levels of risk aversion, there is a sharp decrease in the use of social links for hiring until



(a) Risk Aversion—Mean Wage in Public Market (b) Risk Aversion—Percentage of H-Type Hires

(c) Informativeness—Mean Wage in Public Market (d) Informativeness—Percentage of H-Type Hires

Figure 1: Equilibrium Outcomes

Notes: Theoretical predictions for the experimental parameters $n_F = 4$, $n_L = n_H = 3$, P_L=20, $P_H = 60$, $\lambda_L = 10$, $\lambda_H = 30$. Figure (a): mean accepted wage offers in the public market depending on risk aversion, σ. Figure (b): percentage of H-type workers among all hires depending on risk aversion. For stage 2 of the *Referral* treatment, the dotted line shows the percentage of H-type workers hired combined for public and referral offers; the dash-dotted line shows the corresponding percentage for the public market only. Figures (c) and (d), respectively, show the mean accepted wage and the percentage of H-type hires depending on the probability, α, that two linked workers are equally productive, for fixed risk attitudes of $\sigma = 0.075$.

the differences between the treatments disappear: then, even a 75% probability of hiring an H-type worker is too risky and firms focus on hiring L-type workers through public offers. Overall, the possibility of using referrals is predicted to mitigate the adverse selection problem.[14] Interestingly, however, referral hires in stage 2 can also lead to a "lemons" effect in the public market. This is illustrated by the dotted line in Figure 1(a), showing relatively low average wages in the public market of stage 2 in the *Referral* treatment. As shown in Figure 1(b), the availability of referral offers can thus

[14]The empirical results will reveal that in the experiment a good estimate for firms' CARA coefficient is 0.05, where the possibility of making referral offers promotes hires of H-type workers.

also reduce the overall percentage of H-type hires for higher values of risk aversion.

We have so far assumed that risk attitudes are identical for firms and workers. In Online Appendix B, we explore differential risk attitudes for firms and workers and show that the qualitative predictions remain unchanged. Specifically, we arrive at the following conclusions. Risk aversion on either market side independently leads to intensified adverse selection—either because firms avoid the risk associated with high wage offers or because L-type workers accept lower wages to avoid the risk of not being hired. Hence, on the one hand, referral hiring becomes more important as risk aversion on either market side increases. However, too much risk aversion on either market side diminishes the role of referral hiring, because the correlation in productivity between two linked workers ceases to be sufficiently informative to justify high referral wage offers.[15]

Finally, Figures 1(c) and 1(d) display the effect of changing the parameter α, that is, the correlation in productivity between workers, for a constant level of CARA ($\sigma = 0.075$). The figures show that increasing α increases the average wage and the percentage of H-type hires in stage 1 of the *Referral* treatment relative to *Baseline*. This is because high-productivity stage-1 workers' social links translate to a higher expected profit in stage 2, achieved via referral hiring. Indeed, for sufficiently high α, H-type hires in stage 2 are more common in the *Referral* treatment than in *Baseline*. Interestingly, the availability of referral offers can also lower market efficiency in stage 2 if α is relatively low. The reason for this is the 'lemons effect' of low average wages in the stage 2 public market in the *Referral* treatment (see Figure 1(c)). In the experiment, we implement $\alpha = 0.75$ and expect that referral hiring promotes H-type hires also in stage 2.

3.4. Behavioral Hypotheses

Taken together, the discussion of the theoretical predictions leads to the following hypotheses, which will guide our analysis of the experiment.

Hypothesis 1 (Public Market Wages). Public market wages in stage 1 more frequently meet the reservation wage of H-type workers and generally tend to be higher in *Referral* than in *Baseline*, because firms want to gain access to the social links of H-type workers. In contrast, public market wages in stage 2 tend to be lower in *Referral* than in *Baseline*.

Hypothesis 2 (Referral Offers). In stage 2 of the *Referral* treatment, firms are more likely to use referral offers when they hired an H-type worker in stage 1 than

[15] We also discuss the case of risk-neutral firms. The main effect is that competition between firms for high-productivity workers is fiercer, as firms are less concerned about the risk of hiring an L-type worker at a high wage. The availability of employee referrals is still predicted to improve the average productivity of hired workers, because firms still benefit from using the social links of H-type workers in stage 2.

when they hired an L-type worker. Referral offers are also more likely to meet H-type workers' reservation wage of 30 when firms hired an H-type worker in stage 1 than when they hired an L-type worker.

Hypothesis 3 (H-Type Hires). The percentage of H-type hires is higher in *Referral* than in *Baseline*. This holds in stage 1—where hiring an H-type worker provides access to a valuable social link—as well as in stage 2—where social links are used to hire H-type workers with a higher probability.

4. Empirical Results

We will first discuss offers and accepted wages in Section 4.1, then examine hires and efficiency in Section 4.2, and finally take a more detailed look at the strategies adopted on the individual level and the role of risk aversion in Section 4.3. Recall that the experiment consisted of 15 periods with a stage-1 and a stage-2 market in each period. As we expect participants to try out different behavioral strategies in early periods, in the following, we focus the analysis on the final 10 periods (periods 6 - 15). In online Appendix C, we show that the significant treatment effect between *Baseline* and *Referral* persists when including all periods, and that it becomes more pronounced over time as agents become familiar with the trading environment and their behavior stabilizes.

4.1. Offers and Wages

We start with providing a visual impression of offered and accepted wages over the 120 seconds a market stage was (maximally) open. The panels of Figure 2 show firms' wage offers (upper panels) and accepted wages (lower panels) in both treatments and for the *Referral* treatment separate for public offers and referral offers. To visualize underlying trends, the graphs include lines reflecting smoothed values from locally weighted regressions. There are a few interesting patterns visible.

First, in the public markets of both treatments, firms start by offering wages that are clearly below 30, thus apparently targeting L-type workers. Only towards the end of a trading stage do wage offers increase to the H-type workers' reservation wage of 30 and above. These observations are consistent with firms being engaged in screening behavior. Second, hires at wages below 30 occur throughout the whole time span a trading stage is open, with some concentration at the end of the stage. Third, hires at wages at or above 30 occur predominantly towards the end of a trading stage, mainly in the last 20 seconds. In what follows we provide a quantitative analysis of offers and wages and relate them to Hypothesis 1 and 2.

The first part of our first hypothesis states that in stage 1 public market wages tend to be higher in *Referral* than in *Baseline*, because firms want to hire H-type workers with social links to other high productivity workers and, thus, more frequently offer wages that meet the H-types' reservation wage of 30. The first two rows of Table 1 indicate that the average and median offers of firms do not follow this pattern, and

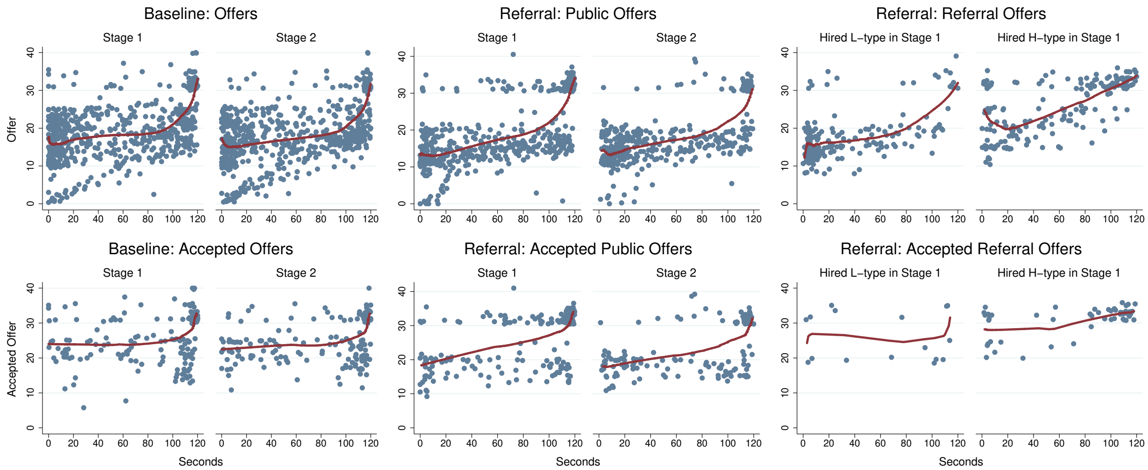


Figure 2: Wage Offers and Accepted Wages

Notes: The first row shows all offers (accepted or not) over time within a trading stage by treatment, stage, and public versus referral offers in *Referral*. The second row shows accepted offers (wages). Graphs include smoothed values from locally weighted regressions.

also the average stage-1 wage (fourth row) is only a little higher in *Referral* than in *Baseline*. However, importantly, the median stage-1 wage (fifth row) in *Referral* is 31, while it is only 25 in *Baseline*, and a Mann-Whitney test indicates that the wage distribution is statistically significantly higher in the former treatment than in the latter treatment ($p = 0.039$).[16] In addition, the third row of the table shows that in stage 1 the percentage of offers greater or equal to 30, is significantly higher in *Referral* than in *Baseline* (26% versus 14%; Mann-Whitney, $p = 0.017$). Thus, despite that there is no treatment difference in average offers and wages, there is a clear tendency that they are higher in *Referral*. Especially, offers above the reservation wage of H-type workers are more frequent, which increases the likelihood to hire such workers and get access to their social links to other H-type workers.

This difference in stage 1 wage offers between treatments is corroborated by random effects regression analyses presented in Table 2, which additionally provide insights into the timing of offers. In regression models (1) and (2), the dependent variable is binary, indicating whether an offer is greater or equal to 30 in stage 1. The explanatory variables are a dummy for the *Referral* treatment and—in model (2)—a dummy *Late* equaling one for offers made in the second half of the market opening time (i.e., after

[16]Unless stated otherwise, all non-parametric tests are two-sided and use session averages as the unit of observation with 5 observations in *Baseline* and 6 observations in *Referral*. We choose this statistical approach to rather err on the conservative side. Therefore, any reported significant effects may be interpreted as a lower bound. In the following, whenever appropriate, we also apply parametric regressions where we exploit the full information of the data set by utilizing individual observations, while controlling for data dependency with clustered or bootstrapped standard errors.

Table 1: Summary of Wage Offers, Accepted Wages, Hires and Efficiency

Treatment:	**Baseline**				**Referral**							
	Stage 1		Stage 2		Stage 1		Stage 2 Overall		Stage 2 Public Offers		Stage 2 Referral Offers	
Type	H	L	H	L	H	L	H	L	H	L	H	L
Offers (mean)	19.1		18.5		18.7		19.5		17.6		21.6	
Offers (median)	19		18		16		18		16		20	
Offers ≥ 30	14%		13%		26%		21%		16%		26%	
Wages (mean)	25.9		25.4		26.5		25.1		23.2		29.7	
Wages (median)	25		25		31		24		20		32	
Wages (mean)	30.9	24.3	31.4	23.6	31.1	24.0	32.0	21.6	31.2	20.8	32.6	25.3
Wages (median)	31	25	31	23	32	21	32	20	31	19	33	24
Wages ≥ 30	88%	30%	92%	23%	92%	44%	95%	23%	92%	22%	100%	28%
Hires (No.)	0.9	2.7	0.8	2.8	1.3	2.4	1.3	2.4	0.6	2	0.7	0.4
Hires (%)	25%	75%	22%	78%	35%	65%	34%	66%	23%	77%	61%	39%
Efficiency	53%		52%		63%		62%		–		–	
Firm Profit	21.5		21.2		25.5		26.4		–		–	
H-type Profit	30.3		30.4		30.5		30.8		–		–	
L-type Profit	22.7		22.7		21.2		19.4		–		–	

Notes: Data from periods ≥ 6. "H" ("L") stands for H-type (L-type) worker. Variables by row: average offers, median offers, and % of offers greater or equal to 30, across both worker types; average wages (i.e., accepted offers) and median wages, across both worker types; average wages, median wages, and % of wages greater or equal to 30, of respectively H- and L-type workers; average number and % of H- and L-type workers hired; efficiency levels as realized gains from trade in % of the first-best outcome where three H-type and one L-type workers are hired; firm, H-type, and L-type worker average unconditional profits.

60 seconds) as well as an interaction between the treatment and the timing of the offer.[17] Regression model (1) shows that in stage 1, offers of at least 30 are significantly more likely in *Referral* than in *Baseline* ($p < 0.001$) and model (2) indicates that this effect is exclusively due to offers made in the second half of the market opening time (*Referral* + *Referral* × *Late* = 0, Wald chi-squared test, $p = 0.002$). Similar conclusions can be drawn for wages (i.e., accepted offers). Regression specification (3) shows that in stage 1, workers are significantly more likely to receive a wage of at least 30 in *Referral* than in *Baseline* ($p = 0.002$), and specification (4) indicates that

[17]For easier interpretation of the estimates, in particular of the interaction terms, the table reports results from linear random effects regressions. Probit random effects regression yield qualitatively identical results.

Table 2: Regression Analysis of Offers and Wages in Stage 1

Dep. Var:	Offer $\geq$ 30		Wage $\geq$ 30	
	(1)	(2)	(3)	(4)
Referral	0.12***	0.00	0.15***	-0.08
	(0.03)	(0.03)	(0.05)	(0.21)
Late (> 60 sec)		0.22***		0.26
		(0.06)		(0.23)
Referral × Late		0.23***		0.31
		(0.09)		(0.27)
Constant	0.02	0.06**	0.33***	0.27
	(0.04)	(0.28)	(0.07)	(0.17)
Wald Test[(a)]		$p = 0.002$		$p < 0.001$
Observations	1197	1197	400	400

Notes: Linear random effects models with cluster-robust (session-level) standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Bootstrap standard errors yield virtually identical results (see online Appendix Cwe show that the treatment effect). Period dummies are included in all regressions. (a) Wald chi-squared tests for the hypothesis 'Referral + Referral × Late' = 0. The reference group in models (1) and (3) is the *Baseline* treatment, whereas in (2) and (4) it is the first 60 seconds of a market stage in *Baseline*.

these wages are accepted mostly during the second half of the market opening time (*Referral* + *Referral* $\times$ *Late* = 0, Wald chi-squared test, $p < 0.001$).

The second part of Hypothesis 1 states that in stage 2 public market wages tend to be lower in the *Referral* treatment than in the *Baseline* treatment. The first and second row in Table 1 show that average and median public offers in stage 2 in *Referral* are indeed lower than in *Baseline* (average: 17.6 vs 18.5, median: 16 vs 18), but not statistically significantly (Mann-Whitney, $p = 0.3602$). Importantly, the treatment difference in stage-2 public market wages is statistically significant. The average (median) wage in the public market in *Referral* is 23.2 (20), whereas in *Baseline* it is 25.4 (25) (Mann-Whitney, $p = 0.044$).[18]

We summarize the above discussion in the following result.

Result 1. *(A) In stage 1, public market wages that are equal or greater than the H-type workers' reservation wage of 30 are more frequent in the Referral treatment than in the Baseline treatment. Median wages are also higher in the Referral treatment. Mean wages do not differ between the treatments. (B) In stage 2, wages in the public market are lower in the Referral treatment than in the Baseline treatment.*

Our analysis largely supports Hypothesis 1 regarding public market wages in stage 1 and stage 2. Specifically, the prediction that the existence of referral hiring in stage 2 gives an incentive to firms to attract high productivity workers by offering wages at or above their reservation wage already in stage 1 is borne out by the data.

Before moving on to the analysis of referral offers we briefly discuss two interesting aspects of our data regarding public market offers and wages. First, given that there are stage-1 treatment differences in median wages and the frequency of offers at or above 30, it seems surprising that the mean offers and wages are very similar. The answer to this apparent puzzle can be found in Figure 2. There, it can be seen from the stage-1 panels 'Baseline: (Accepted) Offers' and 'Referral: (Accepted) Public Offers' that in the *Baseline* treatment most offers (wages) are between 10 and 25, whereas in the *Referral* treatment most offers (wages) are in the range of 10 to 20 (with almost no data points in the range 20 to 25). In other words, conditional on being below 30, offers and wages in *Baseline* are more spread out and tend to be higher than in *Referral*. For this reason, despite the larger percentage of offers greater than 30 and the higher median wage in *Referral*, the mean offer (wage) is similar in both treatments. The theoretical model can partially explain this phenomenon. Specifically, the finding that public offers, *conditional on being below 30*, are lower in *Referral* than in *Baseline* is consistent with the model. This is due to reduced competition in the public market when some workers are hired through referral offers. However, in theory, this effect is more than offset by the higher frequency of offers above 30: the mean offer is predicted to be higher in the *Referral* treatment, but this difference is insignificant in the data.

[18]The difference between treatments in the public-market median wage implies that the median L-type worker hired in the public market is faced with a decline of the payoff (net of the reservation wage of 10) from 15 in *Baseline* to 10 in *Referral*, i.e., a decline of one-third.

Table 3: *Referral* Treatment—Referral Offers and H-type Hires in Stage 2

Dep. Var.	(1) Referral Offer	(2) Offer Level	(3) Offer Level $\geq$ 30	(4) H-type Hire in Stage 2
Hired H-type in Stage 1	0.353***	0.235	0.0665	0.157
	(0.0595)	(1.291)	(0.0723)	(0.124)
Referral Offer (Yes/No)		0.155	-0.0399	0.0396
		(0.425)	(0.0223)	(0.169)
Hired H-type in Stage 1 $\times$ Referral Offer (Yes/No)		7.727***	0.266***	0.323
		(1.128)	(0.0611)	(0.279)
Constant	0.352***	18.657***	0.179***	0.225
	(0.0830)	(0.826)	(0.0445)	(0.126)
Observations	735	735	735	204

Notes: Linear random effects models with cluster-robust (session-level) standard errors in parentheses, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Bootstrap standard errors yield virtually identical results. Dependent variables: 'Referral Offer' = 1 if 'yes', 'Offer Level' equals offered wage level, 'Offer Level $\geq$ 30' = 1 if yes, 'H-type Hire in Stage 2' = 1 if yes. All independent variables are dummy variables equaling 1 if the statement in table is true. Period dummies are included in all regressions. For model (4), a Wald chi-squared test for the hypothesis 'Hired H-type in Stage 1+Hired H-type in Stage 1×Referral Offer' = 0 is rejected at $p < 0.001$.

Second, the treatment differences in public market wages in stage 2 are mainly driven by L-type workers. The rows 'Wages (mean)' and 'Wages (median)' in Table 1 show that their average (median) wage of 23.6 (23) in the *Baseline* treatment exceeds the average (median) wage of 20.8 (19) of such workers hired on the public market in the *Referral* treatment (Mann-Whitney, $p = 0.044$). The reason for the lower wages on the public market in the *Referral* treatment is that the competition between L-type workers is intensified in stage-2 public markets because some firms hire workers through referral offers and do not participate in the public market.

We next examine referral offers and explore if they have the predicted mitigating effect on adverse selection (Hypothesis 2). The right-most panels in Figure 2 show referral offers and accepted wages in stage 2 of the *Referral* treatment, split by whether the worker hired in stage 1 was an L- or H-type. The lower panel suggests that firms which hired an H-type worker in stage 1 more often hire through referral offers in stage 2 than firms which hired an L-type worker in stage 1. In addition, they also seem more likely to make offers equal to or greater than 30. Consistent with this impression, Table 1 shows that in stage 2 of the *Referral* treatment referral offers tend to be higher than public offers (average: 21.6 vs 17.6, median: 20 vs 16). This difference is significant (Wilcoxon signed-rank test, $p = 0.027$).

To test if firms are more likely to use referral offers after they have hired an H-type worker in stage 1 we conduct random effects regressions which are reported in

Table 3. Specification (1) shows that firms are 35.3 percentage points ($p < 0.001$) more likely to make referral offers when they hired an H-type worker in stage 1.[19] The significance of this difference is confirmed also by a Wilcoxon signed-rank test ($p = 0.027$). Specifications (2) and (3), respectively, show that referral offers of firms that hired an H-type in stage 1 are on average 7.72 points higher ($p < 0.001$) and 26.6 percentage points more likely to be at least 30 ($p < 0.001$) than referral offers of firms that hired an L-type worker in stage 1. Together these results support Hypothesis 2, which we summarize as follows.

Result 2. *In stage 2 of the Referral treatment, firms are more likely to use referral offers when they hired an H-type worker in stage 1 than when they hired an L-type worker. Referral offers are also more likely to meet H-type workers' reservation wage of 30 when firms hired an H-type worker in stage 1 than when they hired an L-type worker.*

Moreover, firms which hired a high-productivity worker in stage 1 and used the referral option in stage 2 are relatively successful in hiring H-type workers in stage 2. Specifically, regression specification (4) of Table 3 indicates that firms which have hired an H-type worker in stage 1 and make a referral offer in stage 2 are $15.7 + 32.3 = 48$ percentage points more likely to hire an H-type worker in stage 2 ($p < 0.001$) than those which employed an L-type worker in stage 1. Further, combining public and referral offers, firms are more likely to offer wages at or above 30 in the *Referral* treatment than in the *Baseline* treatment. This can be seen in Table 1 ('Offers $\geq$ 30') which shows that in stage 2 the percentage of all offers exceeding the reservation wage of the H-type worker is 21% in *Referral* and only 13% in *Baseline* (Mann-Whitney, $p = 0.017$).

4.2. Hires and Efficiency

Here we explore the question if the availability of referral hiring helps to alleviate adverse selection, i.e., if it increases the number of H-type hires and thus promotes efficiency (Hypothesis 3).

In Table 1 the rows labeled 'Hires (No.)' and 'Hires (%)' present the average number and the percentage of H- and L-type hires for each treatment and market stage. First, we note that the sum of H- and L-type hires in both treatments and both stages is with 3.6 to 3.7 close to the maximum of 4 hires. In both stages, the total number of hires is not significantly different between the *Referral* and the *Baseline* treatment (Mann-Whitney, $p > 0.404$).[20] Importantly, however, significantly more H-type workers are hired in *Referral* than in *Baseline* ($p = 0.042$ in stage 1, $p = 0.016$

[19] Note that the estimate of the constant of the regression shows that the probability of a referral offer is 35.2% for firms that hired an L-type worker in stage 1. However, the majority of these offers are for a wage of less than 30. Such offers are consistent with the theoretical model, but are redundant as in theory they always imply an equivalent offer made on the public market.

[20] As before, all p-values reported in this sub-section are two-sided and derived from non-parametric Mann-Whitney U tests with session averages as the unit of observation.

in stage 2, $p = 0.021$ overall). The opposite holds for the number of L-type hires ($p = 0.098$ in stage 1, $p = 0.020$ in stage 2, $p = 0.053$ overall). Consequently, in *Referral*, the percentage of H-type workers among all hires is with 35% in stage 1 and 34% in stage 2 significantly larger than in *Baseline* with corresponding percentages of only 25% in stage 1 and 22% in stage 2 ($p = 0.044$ in stage 1, $p = 0.006$ in stage 2, $p = 0.017$ overall).

To test for treatment differences in achieved efficiency levels, we define efficiency as the realized gains from trade divided by the maximally possible gains from trade. The latter is achieved with three H-type hires and one L-type hire, and is given by $3 * (60 - 30) + 1 * (20 - 10) = 100$. In Table 1, the row labeled 'Efficiency' reports the realized efficiency levels for both hiring stages in both treatments. It shows that the availability of referral offers increases efficiency by 10 percentage points ($p = 0.028$). This increase in efficiency is substantial, particularly because the probability that two linked workers have the same type (75%) limits the extent to which referral hiring can raise efficiency. Indeed, for a higher correlation in productivity, the effect size would likely increase. In the two stages two different channels are responsible for the increased efficiency in the *Referral* treatment. In stage 1, efficiency is increased by firms raising wages in anticipation of the stage 2 benefit of hiring an H-type worker in stage 1. In stage 2, efficiency is increased more directly by firms hiring workers through referral offers with an increased likelihood to end up with H-type workers. Taken together, these observations support Hypothesis 3 and constitute clear evidence for the value of social links in alleviating adverse selection. We summarize in the following result.

Result 3. *Both in stage 1 and 2, the number and percentage of H-type workers hired is higher in the Referral treatment than in the Baseline treatment. Consequently, overall efficiency is also higher in the Referral treatment than in the Baseline treatment.*

As predicted by the theoretical literature on job referrals, the increase in market efficiency is associated with an increase in inequality at the cost of L-type workers. The main negative effect for L-type workers comes from the more efficient assignment of workers to firms. Specifically, the number of L-type hires per market stage drops from 2.75 to 2.4 ($p = 0.053$), whereas the number of H-type hires increases from 0.85 to 1.3 ($p = 0.021$). Thus, job referrals prevent some of the L-type workers from finding a job, as these jobs are taken by H-type workers. The increased inequality is best seen when looking at unconditional average profits, i.e., average profits independent of hiring outcomes. We find that firms benefit significantly from referral hiring, with an average profit of 21.33 in *Baseline* and 25.95 in *Referral* ($p = 0.044$). H-type workers are hired more frequently in *Referral*, but they do not earn much more than their outside option of 30 such that the average profit of 30.64 in *Referral* is just slightly larger than the average profit of 30.32 in *Baseline* ($p = 0.273$). Finally, L-type workers' average profits *decrease* due to the introduction of referral hiring, from 22.70 in *Baseline* to 20.31 in *Referral* ($p = 0.017$). The last three rows in Table 1 show the unconditional average profits separated by stage. The described increase in inequality occurs in both stages.

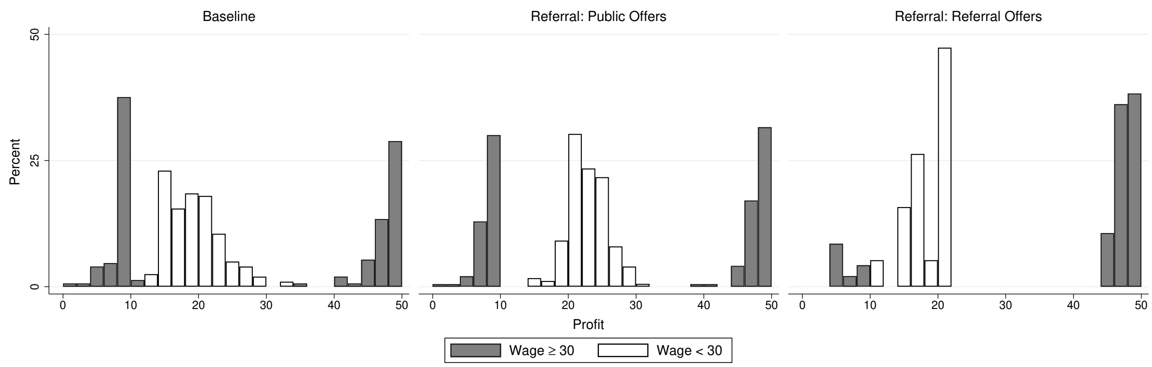


Figure 3: Firm Profits

Notes: Histogram of firm profits separated by whether the accepted wage exceed an H-type worker's reservation wage of 30. Data includes both stages except in the third histogram as referral offers are only made in stage 2 of treatment *Referral*.

Overall, the main benefactors of employee referrals are the firms, and this increases efficiency, but L-type workers are on the losing side.

4.3. Individual Level Analysis: Risk Aversion and Profits

Having established statistical support for our model-based hypotheses, we now take a more detailed look at individual strategies. We pool the data from stage 1 and 2 and first look into firms' strategies followed by an exploration of workers' strategies.

The patterns of offers observed in Figure 2 suggest two main strategies firms may apply when making their offers. First, firms may target L-type workers by offering a wage below 30, even towards the end of the market opening time. According to our model, such a strategy should primarily be used by risk averse firms. Second, firms may attempt to hire H-type workers by, at some point, offering wages of at least 30. This is a more risky strategy as it may lead to hires of L-type workers at relatively high wages. Consequently such a strategy should be used by relatively less risk averse firms.

The difference in riskiness between these two strategies is confirmed by the data. Figure 3 depicts the distribution of firms' profits for both strategies. When the accepted wage offer is below the H-type workers' reservation wage of 30, profits are approximately uni-modal and centered around 20 (transparent bars). Hiring at wages at or above 30 leads to a bi-modal distribution of profits, with profits mostly being either above 45 or below 10 (black bars). The frequency of hiring an H-type worker when the wage is at or above 30 is 51% in *Baseline* and 54% in the public market of the *Referral* treatment. Thus, by using one of the described strategies, participants in the role of firms essentially choose between a relatively certain, intermediate profit and a gamble with a low and a high profits outcome.

Models (1)–(4), in the regression analyses reported in Table 4 look at how firms' different strategies impact their profits. In Model (1), the coefficient of 'Acc. Offer

≥ 30'—which indicates accepted offers of at least 30—shows that in *Baseline* average firm profit is 7.25 points higher for such offers compared to when they are below 30. Thus, firms receive a risk premium for making such high wage offers. Model (2) adds as an explanatory variable a dummy for the hired worker's productivity type. The coefficient of 'Acc. Offer ≥ 30' then shows that firms hiring L-type workers at wages at or above 30 earn on average 12.74 points less than firms hiring at lower wages. At the same time, firms hiring H-type workers at the higher wages earn on average 26.76 ($= -12.74 + 39.50$) points more than firms hiring at lower wages. Accounting for the constant, this implies that firms could go for either a certain payoff of 19.97 (when making offers around 20) or a 50-50 bet on receiving a payoff of either 7.23 ($= 19.97 - 12.74$) or 46.73 ($= 19.97 - 12.74 + 39.50$). It follows that in the *Baseline* treatment, indifference between the certain payoff and the gamble implies a CARA coefficient of 0.044 (or a CRRA coefficient of 0.89). These average risk coefficients are broadly in line with the literature on risk elicitation (see, e.g., the high-stake treatment in Holt and Laury, 2002, and Dave et al., 2010).[21] Models (3) and (4) report the regressions for the *Referral* treatment. Results are very similar with the additional result that offering high wages is particularly profitable when offers are made through referrals.

When deciding on their acceptance strategy, workers face a different trade-off than firms. In each market (with 4 firms and 6 workers) at least 2 workers will not be hired. L-type workers can either choose to accept a wage below 30 or to hold out for higher wages with a higher risk of being not hired. Models (5)–(8) in Table 4 provide information on the payoff consequences of both strategies. Models (5) and (7) show that in the public markets there is a risk premium of 5.20 (in *Baseline*) and 3.97 (in *Referral*), when holding out for a wage offer of at least 30. Model (6) adds the variable 'Not Hired' accounting for the effect of remaining unemployed. The constant in this model shows that accepting an offer below 30 yields on average a payoff of 21.14. This payoff is almost certain, because workers that accept low offers are almost always hired. The model also indicates that holding out for wage offers of at least 30 results in either a payoff of 32.82 ($= 21.14 + 11.68$) if hired or a payoff of 10.14 ($= 21.14 + 11.68 - 22.68$) if not hired. The latter reflects the L-type workers' reservation wage. The probability that an L-type worker that does not accept offers below 30 is eventually hired amounts to 73%. Therefore, for an L-type worker, holding out for a high wage offer is equivalent to a gamble which earns 32.82 with probability 0.73 and 10.14 with probability 0.27, while accepting a low wage offer gives the option of earning 21.14 almost certainly. From this, the implied risk coefficients of L-type workers are 0.094 for CARA and 1.64 for CRRA. Similar conclusions can be drawn for the *Referral* treatment.

Tying the implied risk aversion parameters back to the model, we can explain why

[21] Consistent with these results, in the online appendix we show that participants that are more likely to target H-type workers, on average, earn more than participants that tend to make only low offers.

Table 4: Firm and L-type Worker Profits in Dependence of Wage Offers and Hiring

Dep. Var.	Firm Profit				L-type Worker Profit			
	Baseline		Referral		Baseline		Referral	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Acc. Offer $\geq$ 30	7.25**	-12.74***	7.08***	-14.89***	5.20*	11.68***	3.97***	14.77***
	(3.32)	(1.49)	(1.33)	(0.66)	(2.75)	(1.64)	(1.13)	(0.85)
H-type		39.50***		40.04***				
		(0.42)		(0.14)				
Not Hired						-22.68***		-22.36***
						(0.93)		(0.33)
Referral Offer (RO)			-6.47***	-4.30***			5.74***	4.58***
			(1.65)	(0.60)			(1.21)	(0.78)
Acc. Offer $\geq$ 30 $\times$ RO			17.19***	4.01***			7.01***	-3.13**
			(1.47)	(0.65)			(1.49)	(1.34)
Constant	20.88***	19.97***	24.38***	22.10***	20.88***	21.14***	18.77***	18.51***
	(2.80)	(1.42)	(2.42)	(0.63)	(0.69)	(1.03)	(1.80)	(0.58)
Observations	349	349	429	429	299	299	356	356
Subjects (Sessions)	20 (5)	20 (5)	24 (6)	24 (6)	60 (5)	60 (5)	72 (6)	72 (6)

Notes: Linear mixed effects models with subject and session random intercept; cluster-robust standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Bootstrap standard errors yield qualitatively identical results. Data include both stages. 'Acc. Offer ≥ 30' is a dummy variable that equals 1 if the accepted offer is not smaller than 30; 'H-type' is a dummy variable equal to 1 if the hired worker is of the H-type; 'Referral Offer' is a dummy variable that is equal to 1 if the accepted offer in stage 2 is a referral offer; 'Not Hired' is a dummy variable that is equal to 1 if a L-type worker is not hired in a stage and period. The reference groups for *Baseline* are accepted offers below 30 in models (1) and (5), and offers below 30 accepted by an L-type worker in models (2) and (6). The reference group for *Referral* are accepted offers below 30 in the public market models (3) and (7), and offers below 30 made in the public market and accepted by an L-type worker in models (4) and (8). Period and stage dummies are included in all regressions.

too many L-type workers are hired relative to the second-best efficient outcome.[22] In particular, for the derived CARA parameters between 0.044 and 0.094, Figure 1 shows that the average wage predicted by the model is below 30. This implies that in equilibrium firms and L-type workers with these risk preferences start by offering and accepting, respectively, low wages and only once a fraction of the L-type workers has accepted does the model predict wage offers ≥ 30, in line with the data.

Interestingly, the implied degree of risk aversion appears to be substantially higher for L-type workers than for firms. A possible explanation for this might be that L-type workers underestimate the likelihood of being hired when holding out for a wage offer ≥ 30 (the H-type workers reservation wage). In that case, the risk aversion estimated from L-type workers acceptance behavior would be overestimated. To see if this holds,

[22] We refer to second-best efficiency here as the relevant benchmark because in environments with adverse selection first-best outcomes can typically not be supported in equilibrium by any mechanism (Samuelson, 1984).

in Figure 4 we look at the number of workers of each type that are still on the market when wage offers reach the H-type workers reservation wage and the chance for each type to be hired at such wage offers. The black bars depict the number of workers that are still on the market when wage offers reach 30, and the gray bars show the number of workers that are eventually hired at a wage greater or equal to 30. The former show that all three H-type workers are still on the market and can be hired, whereas about two-thirds of the L-type workers have already left the market because they accepted a lower wage. At the same time, the gray bars show that the likelihood of being hired is fairly equal for H- and L-type workers, despite the fact that there are many more H-type workers available for hire.[23]

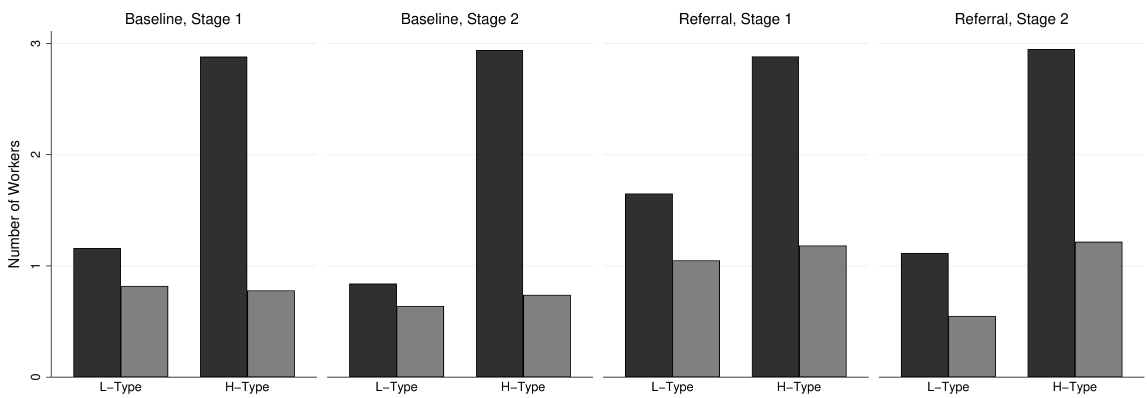


Figure 4: Supply and Hires of Workers at (and above) H-Type Worker's Reservation Wage

Notes: Black bars show the average number of workers (separated by treatments, stages, and productivity type) that are active on the market when wage offers reach the H-type workers' reservation wage of 30. Gray bars show the average number of workers that are hired at wages at or above 30.

An intuitive reason for this is that for wages close to H-type workers' reservation wage the gains from accepting an offer are much larger for L-type workers than for H-type workers. Thus, L-type workers tend to be quicker than H-type workers in accepting offers of 30 or slightly above. More precisely, for wage offers equal to or greater than 30 posted on the public market, the average time to acceptance is 1.09 seconds if accepted by an L-type worker and 1.38 seconds if accepted by an H-type worker (Mann Whitney, $p = 0.063$)—the fast acceptance times are expected given that offers are rarely significantly larger than 30 and hence workers have little incentive to delay acceptance. If L-types underestimate the probability of being hired when holding out for a high wage, this could explain the estimated relatively high risk aversion of

[23]For completeness we note that in stage 2 of the *Referral* treatment (panel 'Referral, Stage 2' in the figure) the number of H-type workers hired at wages of at least 30 is larger than the number of L-type workers. This happens because, due to the social link between workers, in this case referral offers are targeted primarily at H-type workers.

these workers. Another factor that could explain the pattern observed in Figure 4 and the relatively high implied risk aversion for L-types are social preferences. Even if L-types correctly anticipate that they have the possibility to hold out for wages above 30 and still be hired with a high probability, they may not want to exploit this opportunity at the detriment of a firm, particularly when the wage offers targeted at L-type workers are on average allocating more than half of the gains from trade to them.

Another possible explanation relates to the difference in the nature of the gamble firms and workers are facing on the market. Specifically, a worker may derive disutility from the outcome where she is not hired, beyond the immediate payoff consequences. Such a 'displeasure of being unemployed' is reminiscent of the opposite idea of the 'joy of winning' in the auction literature (e.g., Dohmen et al., 2011). With our experiment we cannot disentangle these different explanations, or exclude that there are alternative explanations. The key point of Figure 4, however, is that fewer H-type workers are hired than what would be possible given the firms' wage offers, because H-type workers are slower/less likely to accept wage offers above but close to their reservation wage than L-type workers. This behavior is intuitive, but unfortunately further exacerbates adverse selection.

5. Conclusion

We have investigated whether employers, by utilizing the social links of their workers, succeed in alleviating the negative effects of information asymmetry in labor markets. In our experimental and theoretical setup, we mirror the empirical observation that employee referrals—which operate through social links—can often be informative about the productivity of prospective workers. Our theoretical model predicts important effects of employee referrals for aggregate market outcomes, including higher average productivity and wage premiums internalizing the benefits of employees' social links. Our empirical results provide support for the theoretical hypotheses. In particular, we document significant treatment effects on efficiency and wages when comparing experimental markets featuring employee referrals to markets without employee referrals.

In addition, two empirical results stand out. First, we find that employee referrals lead to higher wages not only for new workers that are hired via referral offers, but also for incumbent workers that have been hired in the competitive market with publicly posted offers. While this finding is predicted by the model—firms are willing to raise wage offers in the competitive market in order to increase the probability of hiring high-productivity workers, which are more likely to have a high-productivity social link—it requires taking into account non-trivial trade offs on the part of the firms.

Second, we find that, despite the benefits of employee referrals and social links, market efficiency still falls short of the second-best outcome. This can be explained by risk aversion, inducing employers to predominantly start out by making low wage offers, which only low-productivity employees are willing to accept. In addition, our data indicate that low-productivity workers' willingness to accept such offers is 'too high', in the sense that this behavior can only be explained by substantially higher levels of risk aversion than those observed for individuals in the role of employers. This is likely due to a novel empirical regularity that we document for high wage offers, and which is insufficiently anticipated by low-productivity workers: low-productivity workers are over-proportionally hired at wages that exceed the high-productivity workers' reservation wage due to market dynamics where low-productivity workers are quick at accepting such offers, whereas high-productivity workers are less eager to accept (their opportunity cost of delaying acceptance is lower). From a methodological standpoint, identifying the effects of risk aversion on market dynamics in the lab is potentially useful for the interpretation of field data, where the consequences of risk preferences are generally difficult to estimate (e.g., Blundell et al., 2019; van Huizen and Alessie, 2019). For example, unexplained variation in risk parameter estimates may be explained by market dynamics or behavioral effects similar to those identified in this study.

Our research has implications that go beyond the labor market setting. It broadly contributes to the question of how to promote efficiency in markets impaired by asymmetric information.[24] The key features of information transmission in our setting are (*i*) the availability of a signal correlated with productivity/quality, (*ii*) that agents must take a risk in order to gain access to the signal, and (*iii*) the private nature of information. With regard to points (*i*) and (*ii*), mechanisms other than employee referral can reveal similar information. As examples, consider the market for graduates from highly-rated schools, where recruiters are willing to pay wage premiums in exchange for a noisy signal of quality (e.g., Altonji and Pierret, 2001; Bordón and Braga, 2020; Oyer and Schaefer, 2019) or commercial services in the market for used cars that provide information for fees. We emphasize, however, that in our setting, information cannot be obtained as directly as when recruiters target higher-rated schools, or when buying an inspection report for a car. Instead, the quality signal is endogenous. It is based on a sorting of workers in stage 1 of our market, which is itself a result of equilibrium behavior. With regard to point (*iii*), an interesting question for future research is how important it is that referral information is private and network-based as opposed to publicly available. There is a literature examining the efficiency of trading institutions depending on the transparency of offers (e.g., Hörner and Vieille, 2009; Fuchs et al., 2016; Bochet and Siegenthaler, 2021). It finds that more transparency often discourages investment from the uninformed market participants to obtain quality signals. In our setting, the reason for this adverse effect is easy to understand: if referral offers were observed by all firms, firms could at least partially infer the quality of workers from these offers, and hence raising wages to gain access to higher productivity social networks would lose much of its appeal.

Finally, our study contributes to a research agenda in experimental economics in-

[24] We are grateful to an anonymous referee who pointed us to this broader contribution of our study.

vestigating competitive markets in the presence of incomplete information[25], and in particular to a number of studies exploring different mechanisms that can alleviate informational inefficiencies. A common finding in this literature is that the degree of equilibrium play tends to be high. That is, people often recognize and utilize the strategic opportunities offered by mechanisms such as quality signaling (Miller and Plott, 1985; Kübler et al., 2008), screening contracts (Cabrales et al., 2011; Hoppe and Schmitz, 2015; Mimra and Waibel, 2018), cheap-talk (Siegenthaler, 2017), or bargaining (Bochet and Siegenthaler, 2018, 2021).[26] Our results demonstrate that the same applies in the context of employee referrals. Given the prevalence of referral hiring in labor markets, our results contribute to closing a gap in this literature.

An important question concerns the ecological validity of our laboratory experiment. We provide three responses to this. First, one aspect of our study is to test theoretically predicted effects. As Falk and Heckman (2009) point out, "for the purpose of testing theories, [representative evidence] is not a problem because most economic models derive predictions that are independent of assumptions concerning participant pools" (p. 537), which is also the case for our study. Second, many experiments have been run with non-student participants, see Charness and Kuhn (2011) for an overview of earlier studies, and Cooper and Kagel (2016), Riedl and Smeets (2017), and Snowberg and Yariv (2021) for more recent evidence. These studies mostly show that behavior of non-student participants is similar to that of student participants. Moreover, some of our findings serve as confirmatory evidence for results previously reported in field studies (see the introduction) and thus contribute to the development of a consistent body of evidence on the effects of employee referrals. Third, we believe that the decisions the participants make in the experiment are akin to those workers and recruiters make in daily life, at least in terms of our key variables of interest: information and risk. Naturally, this does not guarantee that the behavior we observe in our experiment will also be observed in every circumstance in the field. Ultimately, this is an empirical question that we consider to be an interesting avenue for future research.

Recent evidence suggests that recruitment via job networks may disadvantage qualified women (Beaman et al., 2018) and reduce intergenerational social mobility (Magruder, 2010). Other potential downsides of referral hiring include rent-seeking by hiring managers and negative moral judgments toward employees that benefit from

[25]Seminal contributions include Smith (1962, 1965, 1982), Plott and Smith (1978), Fehr et al. (1993) and Fehr and Falk (1999).

[26]Other experimental studies have focused on moral hazard in labor market settings. Fehr et al. (1993) and Fehr et al. (1997), in line with Akerlof (1982, 1984), developed the gift exchange game showing that reciprocal fairness may overcome moral hazard. Bartling et al. (2012) and Brown et al. (2004) examine the difference between trust and control-based contracts on labor market outcomes, and Schram et al. (2010) compare how firms choose between hiring on a competitive market versus hiring through bilateral negotiations. Andreoni (2017) finds that selling goods with a "satisfaction guarantee" helps mitigate problems of moral hazard.

referrals from high-power individuals (e.g., Derfler-Rozin et al., 2018). More generally, Montgomery (1991b) and Calvo-Armengol and Jackson (2004) present theoretical network models where individuals that are not well-connected are at a disadvantage and thus networks can perpetuate inequality. Our results show that firms are the main benefactor of referral hiring, and that, consistent with previous studies, it leads to an increase in inequality among workers compared with the counterfactual without referral hiring. At the same time, it stands to reason that social groups that are not well-connected (e.g., first-time job seekers or immigrants) are often groups of which little objective information is available. Employee referrals, as a source of credible information, could thus be particularly effective for such groups and may even mitigate labor market discrimination. Examining mechanisms that mitigate or exacerbate discrimination in referral networks is an interesting future research line.

References

Akerlof, George, "The market for "lemons": Quality uncertainty and the market mechanism," *The Quarterly Journal of Economics*, 1970, pp. 488–500.

_ , "Labor contracts as partial gift exchange," *The Quarterly Journal of Economics*, 1982, *97* (4), 543–569.

_ , "Gift exchange and efficiency-wage theory: Four views," *American Economic Review*, 1984, *74* (2), 79–83.

Altonji, Joseph and Charles Pierret, "Employer learning and statistical discrimination," *The Quarterly Journal of Economics*, 2001, *116* (1), 313–350.

and, Emilio Fernandez Roberto and Paul Moore, "Social capital at work: Networks and employment at a phone center," *American Journal of Sociology*, 2000, *105* (5), 1288–1356.

Andreoni, James, "Satisfaction Guaranteed: When Moral Hazard meets Moral Preferences," *American Economic Journal: Microeconomics*, 2017, *74* (5), 1365–1384.

Arrow, Kenneth, "Uncertainty and the welfare economics of medical care," *American Economic Review*, 1963, *53* (5), 941–973.

Baert, Stijn, "Hiring a gay man, taking a risk? A lab experiment on employment discrimination and risk aversion," *Journal of homosexuality*, 2018, *65* (8), 1015–1031.

Barr, Tavis, Raicho Bojilov, and Lalith Munasinghe, "Referrals and search efficiency: Who learns what and when?," *Journal of Labor Economics*, 2019, *37* (4), 1267–1300.

Bartling, Björn, Ernst Fehr, and Klaus Schmidt, "Screening, competition, and job design: Economic origins of good jobs," *American Economic Review*, 2012, *102* (2), 834–64.

Beaman, Lori, "Social networks and the dynamics of labour market outcomes: Evidence from refugees resettled in the US," *The Review of Economic Studies*, 2011, *79* (1), 128–161.

_ **and Jeremy Magruder**, "Who gets the job referral? Evidence from a social networks experiment," *American Economic Review*, 2012, *102* (7), 3574–3593.

_ **, Niall Keleher, and Jeremy Magruder**, "Do job networks disadvantage women? Evidence from a recruitment experiment in Malawi," *Journal of Labor Economics*, 2018, *36* (1), 121–157.

Blundell, Richard, Ran Gu, Søren Leth-Petersen, Hamish Low, and Costas Meghir, "Durables and lemons: private information and the market for cars," Technical Report, National Bureau of Economic Research 2019.

Bochet, Olivier and Simon Siegenthaler, "Better later than never? An experiment on bargaining under adverse selection," *International Economic Review*, 2018, *59* (2), 947–972.

_ **and** _ , "Competition and Price Transparency in the Market for Lemons: Experimental Evidence," *American Economic Journal: Microeconomics*, 2021, *13* (2), 113–40.

Boorman, Scott, "A combinatiorial optimization model for transmission of job information through contact networks," *Bell Journal of Economics*, 1975, pp. 216–249.

Bordón, Paola and Breno Braga, "Employer learning, statistical discrimination and university prestige," *Economics of Education Review*, 2020, *77*, 101995.

Brown, Martin, Armin Falk, and Ernst Fehr, "Relational contracts and the nature of market interactions," *Econometrica*, 2004, *72* (3), 747–780.

Brown, Meta, Elizabeth Setren, and Giorgio Topa, "Do informal referrals lead to better matches? Evidence from a firm's employee referral system," *Journal of Labor Economics*, 2016, *34* (1), 161–209.

Burks, Stephen, Bo Cowgill, Mitchell Hoffman, and Michael Housman, "The value of hiring through employee referrals," *The Quarterly Journal of Economics*, 2015, *130* (2), 805–839.

Cabrales, Antonio, Gary Charness, and Marie Claire Villeval, "Hidden information, bargaining power, and efficiency: An experiment," *Experimental Economics*, 2011, *14* (2), 133–159.

Calvó-Armengol, Antoni, "Job contact networks," *Journal of Economic Theory*, 2004, *115* (1), 191–206.

Calvo-Armengol, Antoni and Matthew Jackson, "The effects of social networks on employment and inequality," *American Economic Review*, 2004, *94* (3), 426–454.

Calvó-Armengol, Antoni and Yves Zenou, "Job matching, social network and word-of-mouth communication," *Journal of Urban Economics*, 2005, *57* (3), 500–522.

Castilla, Emilio, "Social networks and employee performance in a call center," *American Journal of Sociology*, 2005, *110* (5), 1243–1283.

Charness, Gary and Peter Kuhn, "Lab labor: What can labor economists learn from the lab?," *Handbook of Labor Economics*, 2011, *4*, 229–330.

Choudhary, Ali and Paul Levine, "Risk-averse firms and employment dynamics," *Oxford Economic Papers*, 2010, *62* (3), 578–602.

Cooper, David and John Kagel, "Other regarding preferences: A selective survey of experimental results," *The Handbook of Experimental Economics*, 2016, *2*, 217–289.

Currarini, Sergio, Matthew Jackson, and Paolo Pin, "An economic model of friendship: Homophily, minorities, and segregation," *Econometrica*, 2009, *77* (4), 1003–1045.

Dave, Chetan, Catherine Eckel, Cathleen Johnson, and Christian Rojas, "Eliciting risk preferences: When is simple better?," *Journal of Risk and Uncertainty*, 2010, *41* (3), 219–243.

Derfler-Rozin, Rellie, Bradford Baker, and Francesca Gino, "Compromised ethics in hiring processes? How referrers' power affects employees' reactions to referral practices," *Academy of Management Journal*, 2018, *61* (2), 615–636.

Dohmen, Thomas, Armin Falk, Klaus Fliessbach, Uwe Sunde, and Bernd Weber, "Relative versus absolute income, joy of winning, and gender: Brain imaging evidence," *Journal of Public Economics*, 2011, *95* (3-4), 279–285.

Dustmann, Christian, Albrecht Glitz, Uta Schönberg, and Herbert Brücker, "Referral-based job search networks," *The Review of Economic Studies*, 2015, *83* (2), 514–546.

Ekinci, Emre, "Employee referrals as a screening device," *The RAND Journal of Economics*, 2016, *47* (3), 688–708.

Fafchamps, Marcel and Alexander Moradi, "Referral and job performance: Evidence from the Ghana colonial army," *Economic Development and Cultural Change*, 2015, *63* (4), 715–751.

Falk, Armin and James Heckman, "Lab experiments are a major source of knowledge in the social sciences," *Science*, 2009, *326* (5952), 535–538.

_ , Stephan Meier, and Christian Zehnder, "Do lab experiments misrepresent social preferences? The case of self-selected student samples," *Journal of the European Economic Association*, 2013, *11* (4), 839–852.

Fehr, Ernst and Armin Falk, "Wage rigidity in a competitive incomplete contract market," *Journal of Political Economy*, 1999, *107* (1), 106–134.

_ , Georg Kirchsteiger, and Arno Riedl, "Does fairness prevent market clearing? An experimental investigation," *The Quarterly Journal of Economics*, 1993, *108* (2), 437–459.

— , — , and — , "Gift exchange and reciprocity in competitive experimental markets," *European Economic Review*, 1998, *42* (1), 1–34.

— **, Simon Gächter, and Georg Kirchsteiger**, "Reciprocity as a contract enforcement device: Experimental evidence," *Econometrica: Journal of the Econometric Society*, 1997, pp. 833–860.

Fischbacher, Urs, "z-Tree: Zurich toolbox for ready-made economic experiments," *Experimental Economics*, 2007, *10* (2), 171–178.

Frank, Jeff, "Monopolistic competition, risk aversion, and equilibrium recessions," *The Quarterly Journal of Economics*, 1990, *105* (4), 921–938.

Fuchs, William, Aniko Öry, and Andrzej Skrzypacz, "Transparency and distressed sales under asymmetric information," *Theoretical Economics*, 2016, *11* (3), 1103–1144.

Galenianos, Manolis, "Hiring through referrals," *Journal of Economic Theory*, 2014, *152* (1), 304–323.

— , "Referral networks and inequality," *Available at SSRN: https://ssrn.com/abstract=2768083*, 2020.

Galeotti, Andrea and Luca Paolo Merlino, "Endogenous job contact networks," *International Economic Review*, 2014, *55* (4), 1201–1226.

Granovetter, Mark, "Economic action and social structure: The problem of embeddedness," *American Journal of Sociology*, 1985, *91* (3), 481–510.

— , *Getting a job: A study of contacts and careers*, The University of Chicago Press, 1995.

Greenwald, Bruce, "Adverse selection in the labour market," *The Review of Economic Studies*, 1986, *53* (3), 325–347.

Greiner, Ben, "Subject pool recruitment procedures: organizing experiments with ORSEE," *Journal of the Economic Science Association*, 2015, *1* (1), 114–125.

Heath, Rachel, "Why do firms hire using referrals? Evidence from bangladeshi garment factories," *Journal of Political Economy*, 2018, *126* (4), 1691–1746.

Hensvik, Lena and Oskar Nordström Skans, "Social networks, employee selection, and labor market outcomes," *Journal of Labor Economics*, 2016, *34* (4), 825–867.

Holt, Charles and Susan Laury, "Risk aversion and incentive effects," *American Economic Review*, 2002, *92* (5), 1644.

Hoppe, Eva and Patrick Schmitz, "Do sellers offer menus of contracts to separate buyer types? An experimental test of adverse selection theory," *Games and Economic Behavior*, 2015, *89*, 17–33.

Hörner, Johannes and Nicolas Vieille, "Public vs. private offers in the market for lemons," *Econometrica*, 2009, *77* (1), 29–69.

Ioannides, Yannis and Linda Loury, "Job information networks, neighborhood effects, and inequality," *Journal of Economic Literature*, 2004, *42* (4), 1056–1093.

Jackson, Matthew, "An overview of social networks and economic applications," in "The Handbook of Social Economics," Vol. 1, North Holland Press Amsterdam, 2010, pp. 511–585.

_ , *Social and economic networks*, Princeton University Press, 2010.

Kahneman, Daniel and Dan Lovallo, "Timid choices and bold forecasts: A cognitive perspective on risk taking," *Management science*, 1993, *39* (1), 17–31.

Kranton, Rachel and Deborah Minehart, "A theory of buyer-seller networks," *American Economic Review*, 2001, *91* (3), 485–508.

Kübler, Dorothea, Wieland Müller, and Hans-Theo Normann, "Job-market signaling and screening: An experimental comparison," *Games and Economic Behavior*, 2008, *64* (1), 219–236.

Kugler, Adriana, "Employee referrals and efficiency wages," *Labour Economics*, 2003, *10* (5), 531–556.

Levitt, Steven and John List, "What do laboratory experiments measuring social preferences reveal about the real world?," *Journal of Economic Perspectives*, 2007, *21* (2), 153–174.

Loury, Linda Datcher, "Some contacts are more equal than others: Informal networks, job tenure, and wages," *Journal of Labor Economics*, 2006, *24* (2), 299–318.

Lovallo, Dan, Tim Koller, Robert Uhlaner, and Daniel Kahneman, "Your company is too risk-averse," *Harvard Business Review*, 2020, *98* (2), 104–111.

Maccrimmon, Kenneth and Donald Wehrung, "The management of uncertainty: Taking risks," *New York*, 1986.

Magruder, Jeremy, "Intergenerational networks, unemployment, and persistent inequality in South Africa," *American Economic Journal: Applied Economics*, 2010, *2* (1), 62–85.

Mas-Colell, Andreu, Michael Dennis Whinston, Jerry Green et al., *Microeconomic Theory*, Vol. 1, Oxford University Press New York, 1995.

McPherson, Miller, Lynn Smith-Lovin, and James Cook, "Birds of a feather: Homophily in social networks," *Annual Review of Sociology*, 2001, *27* (1), 415–444.

Miller, Ross and Charles Plott, "Product quality signaling in experimental markets," *Econometrica*, 1985, *53* (4), 837–872.

Mimra, Wanda and Christian Waibel, "(Non)Exclusive Contracting Under Adverse Selection: An Experiment," 2018. Available at SSRN: https://ssrn.com/abstract=3037097.

Montgomery, James, "Social networks and labor-market outcomes: Toward an economic analysis," *American Economic Review*, 1991, *81* (5), 1408–1418.

_ , *Social networks and persistent inequality in the labor market*, Center for Urban Affairs and Policy Research, 1991.

Mortensen, Dale and Tara Vishwanath, "Personal contacts and earnings: It is who you know!," *Labour Economics*, 1994, *1* (2), 187–201.

Munshi, Kaivan, "Networks in the modern economy: Mexican migrants in the US labor market," *The Quarterly Journal of Economics*, 2003, *118* (2), 549–599.

Obukhova, Elena and George Lan, "Do job seekers benefit from contacts? A direct test with contemporaneous searches," *Management Science*, 2013, *59* (10), 2204–2216.

Oyer, Paul and Scott Schaefer, "The returns to elite degrees: The case of American lawyers," *ILR Review*, 2019, *72* (2), 446–479.

Pallais, Amanda and Emily Glassberg Sands, "Why the referential treatment? Evidence from field experiments on referrals," *Journal of Political Economy*, 2016, *124* (6), 1793–1828.

Pellizzari, Michele, "Do friends and relatives really help in getting a good job?," *Industrial Labor & Relations Review*, 2010, *63* (3), 494–510.

Pieper, Jenna, Charlie Trevor, Ingo Weller, and Dennis Duchon, "Referral hire presence implications for referrer turnover and job performance," *Journal of Management*, 2019, *45* (5), 1858–1888.

_ , Jessica Greenwald, and Steven Schlachter, "Motivating employee referrals: The interactive effects of the referral bonus, perceived risk in referring, and affective commitment," *Human Resource Management*, 2018, *57* (5), 1159–1174.

Pissarides, Christopher, *Equilibrium unemployment theory*, MIT Press, 2000.

Plott, Charles and Vernon Smith, "An experimental examination of two exchange institutions," *The Review of Economic Studies*, 1978, *45* (1), 133–153.

Rees, Albert, "Information networks in labor markets," *American Economic Review*, 1966, *56* (1/2), 559–566.

Riedl, Arno and Paul Smeets, "Why do investors hold socially responsible mutual funds?," *Journal of Finance*, 2017, *72* (6), 2505–2550.

Rubineau, Brian and Roberto Fernandez, "Missing links: Referrer behavior and job segregation," *Management Science*, 2013, *59* (11), 2470–2489.

Samuelson, William, "Bargaining under asymmetric information," *Econometrica*, 1984, pp. 995–1005.

Schmutte, Ian, "Job referral networks and the determination of earnings in local labor markets," *Journal of Labor Economics*, 2014, *33* (1), 1–32.

Schram, Arthur, Jordi Brandts, and Klarita Gërxhani, "Information, bilateral negotiations, and worker recruitment," *European Economic Review*, 2010, *54* (8), 1035–1058.

Siegenthaler, Simon, "Meet the lemons: An experiment on how cheap-talk overcomes adverse selection in decentralized markets," *Games and Economic Behavior*, 2017, *102*, 147–161.

Smith, Vernon, "An experimental study of competitive market behavior," *Journal of Political Economy*, 1962, *70* (2), 111–137.

_ , "Experimental auction markets and the Walrasian hypothesis," *Journal of Political Economy*, 1965, *73* (4), 387–393.

_ , "Microeconomic systems as an experimental science," *American Economic Review*, 1982, *72* (5), 923–955.

Snowberg, Erik and Leeat Yariv, "Testing the waters: Behavior across participant pools," *American Economic Review*, 2021, *111* (2), 687–719.

Stigler, George, "Information in the labor market," *Journal of Political Economy*, 1962, *70* (5, Part 2), 94–105.

Topa, Giorgio, "Social interactions, local spillovers and unemployment," *The Review of Economic Studies*, 2001, *68* (2), 261–295.

_ , "Labor markets and referrals," in "Handbook of Social Economics," Vol. 1, Elsevier, 2011, pp. 1193–1221.

van Huizen, Thomas and Rob Alessie, "Risk aversion and job mobility," *Journal of Economic Behavior & Organization*, 2019, *164*, 91–106.

Weller, Ingo, Brooks Holtom, Wenzel Matiaske, and Thomas Mellewigt, "Level and time effects of recruitment sources on early voluntary turnover.," *Journal of Applied Psychology*, 2009, *94* (5), 1146.

Wilson, Charles, "The nature of equilibrium in markets with adverse selection," *The Bell Journal of Economics*, 1980, pp. 108–130.

Yakubovich, Valery and Daniela Lup, "Stages of the recruitment process and the referrer's performance effect," *Organization Science*, 2006, *17* (6), 710–723.

Zeltzer, Dan, "Gender homophily in referral networks: Consequences for the medicare physician earnings gap," *American Economic Journal: Applied Economics*, 2020, *12* (2), 169–97.

Zenou, Yves, "Social interactions and the labor market," *Revue d'économie politique*, 2013, *123* (3), 307–331.

Appendix

A. Equilibrium Characterization

This appendix derives the market equilibria. We will construct the symmetric equilibria. We also focus on the market structure relevant to the experiment where $n_S \equiv n_L + n_H \geq n_F > n_L$. Moreover, $P_H - \lambda_H > P_L - \lambda_L$. Let $\hat{n}_F \equiv n_F - 1$ and similarly for workers.

A.1. Equilibrium in Baseline

It is sufficient to discuss equilibrium behavior in stage 1 (identical predictions apply to stage 2 since the stages are independent). Notice that $n_F \leq n_S$ implies that the highest offer is λ_H. Moreover, all firms always include λ_H in their set of wage offers: We will show below that at equilibrium L-type workers accept offers $w^* < \lambda_H$ with probability (w.p.) 1. Thus, when offering a wage $w^* < \lambda_H$, it is always profitable for firms to also offer λ_H, as the latter offer will only be accepted if no L-type workers are left in the market.

Consider next the following equation for L-type workers:

$$u_L(w) = \frac{n_F - q}{n_S - q} u_L(\lambda_H) + \frac{n_S - n_F}{n_S - q} u_L(\lambda_L). \tag{A.1}$$

If $q = \hat{n}_L$, the wage $\underline{w}$ solving (A.1) represents a lower bound for acceptable wages. For any lower wage, an L-type worker prefers to wait for the offer λ_H, even if $q = \hat{n}_L$ firms and other L-type workers have left the market and the probability to be hired at a wage of λ_H is only $(n_F - \hat{n}_L)/(n_S - \hat{n}_L)$. Similarly, the wage $\bar{w}_1$ solving (A.1) for $q = 0$ yields the wage level above which L-type workers accept with probability 1.

On the firms' side, an upper bound for wage offers below λ_H is reached if they prefer offering λ_H immediately rather than hiring an L-type worker at a wage that exceeds $\bar{w}_2$:

$$u_F(P_L + B - \bar{w}_2) = \Psi(\lambda_H). \tag{A.2}$$

where

$$\Psi(\lambda_H) = \frac{n_L}{n_S} u_F(P_L + B - \lambda_H) + \frac{n_H}{n_S} u_F(P_H + B - \lambda_H). \tag{A.3}$$

denotes a firm's expected utility when offering λ_H and all workers are still in the market. The parameter B is a baseline productivity, set to $B = 20$ in the experiment.

Suppose that at equilibrium firms offer $\{\lambda_H\}$ with probability β^* and $\{w^*, \lambda_H\}$ with probability $1 - \beta^*$. We claim that $w^* < \lambda_H$ can be supported as an equilibrium wage only if $w^* \in [\underline{w}, \min(\bar{w}_1, \bar{w}_2)]$. We prove the claim:

- From (A.1) it follows directly that wages below $\underline{w}$ are always rejected. Further, we must have $w^* \leq \bar{w}_2$ for if not (A.2) implies that firms strictly prefer to offer $\{\lambda_H\}$. Finally, we must have $w^* \leq \bar{w}_1$. If not, firms would have an incentive to offer a lower wage. Let n_{FL} be the number of firms offering $\{w^*, \lambda_H\}$. If $n_{FL} \leq n_L$, a firm is guaranteed to hire an L-type workers with any offer $w > \bar{w}_1$. If $n_{FL} > n_L$ firms may not hire an L-type worker (if other firms offer more), but in this case the firm prefers to hire at the wage λ_H as it implies that they hire an H-type w.p. 1 (and earn strictly more due to the higher gains from trade). Notice that L-type workers must accept $w^* < \lambda_H$ with probability 0 or 1. If they accept with a positive probability less than 1, firms could slightly lower the wage to $w^* - \epsilon$, knowing that L-type workers would accept such an offer in return for a strictly higher probability to get hired if $n_{FL} \leq n_L$ (as wages are cleared from below) or they would hire an H-type at λ_H in case $n_{FL} > n_L$.

There is more than one possible equilibrium wage level below λ_H. To see this, let $w_{FL} \leq \bar{w}_1$ be the solution to (A.1) for $q = \min(\hat{n}_L, n_{FL})$. If $w^* < w_{FL}$, L-type workers reject w^* given the realization of n_{FL}. If $w^* \in [w_{FL}, \bar{w}_1]$, L-type workers face a coordination problem: if $\hat{n}_L$ L-type workers accept w^* the remaining worker want to accept as well, but similarly if $\hat{n}_L$ L-type workers reject w^* so does the remaining one. The reason is that the risk of not being hired increases in the number of other L-type workers that accept w^*, see (A.1). The threshold wage level at which L-type workers switch from accepting w^* to rejecting $w^* - \epsilon$ can thus be anywhere in $[w_{FL}, \bar{w}_1]$. At the threshold, firms also don't deviate to higher offers, because at equilibrium they are indifferent between offering $\{\lambda_H\}$ and $\{w^*, \lambda_H\}$, i.e. they don't want to hire an L-type worker at wage larger than w^*. Hence, the supportable wage levels can go as low as $w^* = \underline{w}$.

Now, offering $\{\lambda_H\}$ yields an expected utility of

$$U_F(\{\lambda_H\}; \hat{n}_{FL}) = \frac{n_L - \min(\hat{n}_{FL}, n_L)}{n_S - \min(\hat{n}_{FL}, n_L)} u_F(P_L + B - \lambda_H) + \frac{n_H}{n_S - \min(\hat{n}_{FL}, n_L)} u_F(P_H + B - \lambda_H). \quad \text{(A.4)}$$

Offering $\{w^*, \lambda_H\}$ yields an expected utility of

$$U_F(\{w^*, \lambda_H\}; \hat{n}_{FL}) = \Psi(\lambda_H) \quad \text{(A.5)}$$

if $w^* < w_{FL}$ and of

$$U_F(\{w^*, \lambda_H\}; \hat{n}_{FL}) = \frac{\min(n_L, n_{FL})}{n_{FL}} u_F(P_L + B - w^*) + \left(1 - \frac{\min(n_L, n_{FL})}{n_{FL}}\right) u_F(P_H + B - \lambda_H) \quad \text{(A.6)}$$

if $w^* \geq w_{FL}$. The equilibrium probability β^* of offering $\{\lambda_H\}$ renders firms indifferent between $\{\lambda_H\}$ and $\{w^*, \lambda_H\}$:

$$\sum_{i=0}^{\hat{n}_F} (1 - \beta^*)^i (\beta^*)^{\hat{n}_F - i} \binom{\hat{n}_F}{i} [U_F(\{\lambda_H\}; i) - U_F(\{w^*, \lambda_H\}; i)] = 0. \quad \text{(A.7)}$$

The solutions to (A.4) - (A.7) for $w^* = \underline{w}$ and $w^* = \bar{w}_1$ give the relevant bounds for the minimum and maximum number of hired L-type workers. The equilibrium reported in Figure 1 is for $w^* = \bar{w}_1$. Note that if expression (A.7) exceeds 0 even for $\beta = 1$, the equilibrium value is $\beta^* = 1$ (the opposite case never occurs if $n_F > n_L$ and the gains from trade are larger with H-type workers).

A.2. Equilibrium in Referral

Denote the parameter for the correlation in productivity between linked workers by $\alpha > \max(1/2, n_H/n_S)$. Without the condition on α the model wouldn't make sense as L-type workers would be more likely than H-type workers to have a social link to an H-type (see also Montgomery, 1991a).

We first show that firms that hired an L-type worker in stage 1 don't make a referral offer in stage 2.

Lemma A.1. Firms that have hired a stage-1 L-type worker do not benefit from the option to make referral offers in stage 2, i.e., their expected utility when hiring in the public market is larger than when hiring through referral offers.

Proof: Suppose that only firms with an H-type stage-1 worker make a referral offers and in stage 1 all firms offered $\{\lambda_H\}$. Then the expected fraction of H-type workers active in the stage-2 public market is at a minimum and equals

$$\frac{n_H - \frac{n_H}{n_S} n_F \alpha}{n_S - \frac{n_H}{n_S} n_F} > 1 - \alpha \tag{A.8}$$

where $\frac{n_H}{n_S} n_F$ is the expected number of firms with a stage-1 H-type hire and the inequality follows from plugging in $\alpha > \max(1/2, n_H/n_S)$. Hence the expected fraction of H-type workers active in the stage-2 public market is strictly higher than $1 - \alpha$. The latter is the probability to hire an H-type worker through a referral offer for a firm with a stage-1 L-type worker. It follows that for a firm with a stage-1 L-type worker the referral offer of $\{\lambda_H\}$ (or higher) is strictly dominated by the same offer in the public market. Referral offers below λ_H are inconsequential: they are rejected by H-type workers and L-type workers willing to accept such offers will do so in the public market as well. $\square$

When workers choose which wages to accept in the stage-2 public market, they are aware of the number of firms f and the number of workers s still active in the market (in the experiment individuals weren't explicitly informed about referral hires but they could observe other firms' behavior in the public market, i.e., no activity in the public market indicates that a firm hires a worker through a referral offer). Similarly to (A.1), the wage surely accepted by L-type workers $\bar{w}_1^2(f, s)$ follows from solving

$$u_L(\bar{w}_1^2(f, s)) = \frac{f}{s} u_L(\lambda_H) + \frac{s - f}{s} u_L(\lambda_L). \tag{A.9}$$

The maximum wage $\bar{w}_2^2$ below λ_H a firm is willing to offer, similarly to (A.3), follows from

$$u_F(P_L + B - \bar{w}_2^2) = \Psi(\lambda_H, f, s) \tag{A.10}$$

where, letting $\bar{f} = n_F - f$ be the number of firms that hired through a referral offer,

$$\Psi(\lambda_H, f, s) = \sum_{i=0}^{\bar{f}} \alpha^i (1-\alpha)^{\bar{f}-i} \binom{\bar{f}}{i} \left(\frac{n_L - (\bar{f} - i)}{s} u_F(P_L + B - \lambda_H) + \frac{n_H - i}{s} u_F(P_H + B - \lambda_H) \right). \tag{A.11}$$

As in the *Baseline* treatment, firms mix between $\{\lambda_H\}$ and $\{w^{2,*}, \lambda_H\}$. For simplicity, let us focus on $w^{2,*} = \bar{w}_1^2(f, s)$ (equilibria for the other possible wage levels are derived analogous to the *Baseline*). Let $fl \leq f$ be the number of firms offering $\{w^{2,*}, \lambda_H\}$. The expected utility *conditional* on l, h, and fl when offering $\{\lambda_H\}$ is

$$U_F(\{\lambda_H\}; l, h, \hat{fl}) = \frac{l - \min(\hat{fl}, l)}{s - \min(\hat{fl}, l)} u_F(P_L + B - \lambda_H) + \frac{h}{s - \min(\hat{fl}, l)} u_F(P_H + B - \lambda_H). \tag{A.12}$$

Offering $\{w^{2,*}, \lambda_H\}$ yields an expected utility of

$$U_F(\{w^{2,*}, \lambda_H\}; l, h, \hat{fl}) = \frac{\min(l, fl)}{fl} u_F(P_L + B - w^{2,*}) + \left(1 - \frac{\min(fl, l)}{fl}\right) \left[\frac{h}{s-l} u_F(P_H + B - \lambda_H)\right]. \tag{A.13}$$

The equilibrium value $\beta^{2,*}$ with which firms in the public stage-2 market choose to offer $\{\lambda_H\}$ follows from solving

$$\sum_{i=0}^{\hat{f}} (1-\beta^{2,*})^i (\beta^{2,*})^{\hat{f}-j} \binom{\hat{f}}{i} \sum_{j=0}^{\bar{f}} \alpha^j (1-\alpha)^{\bar{f}-j} \binom{\bar{f}}{j} \left[U_F(\{\lambda_H\}; l, h, \hat{fl}) - U_F(\{w^{2,*}, \lambda_H\}; l, h, \hat{fl})\right] = 0. \tag{A.14}$$

If (A.14) exceeds 0 even for $\beta^{2,*} = 1$, the equilibrium value is $\beta^{2,*} = 1$ and vice versa for $\beta^{2,*} = 0$. This fully characterizes behavior in the public market of stage 2 in the *Referral* treatment.

The next question is whether firms that hired an H-type worker in stage 1 will make a referral offer. We denote the probability with which firms make such an offer by γ. The expected utility when hiring through a referral offer is

$$\Psi_r(\lambda_H) = (1-\alpha) u_F(P_L + B - \lambda_H) + \alpha u_F(P_H + B - \lambda_H). \tag{A.15}$$

The expected utility when offering in the stage-2 public market depends on $\beta^{2,*}$, which we derived in (A.14), on the number y of other firms that have hired at a wage of λ_H in stage 1 (this is observed), and on the probability γ with which such firms make referral offers. The expected utility is given by

$$U_F^2(\gamma, y) = \sum_{q=0}^{\min(\hat{n_H}, y)} \frac{\left(\mathbb{1}_{q=0} + \prod_{j=1}^{q-1}(\hat{n_L} - j)\right)\left(\mathbb{1}_{q=y} + \prod_{j=0}^{y-q-1}(n_L - j)\right)}{\prod_{j=0}^{y-1}(\hat{n_S} - j)} \binom{y}{q} \sum_{i=0}^{q} \gamma^i (1-\gamma)^{q-i} \binom{q}{i} U_F^2(n_F - i) \tag{A.16}$$

where the first term cycles through the probabilities that in stage 1 $q = 0$ to $q = \min(\hat{n_H}, y)$ other firms have hired an H-type worker (from the perspective of a firm that hired such a worker), the second term determines the number of referral hires i given q, and $U_F^2(n_F - i)$ is the expected utility in the stage-2 public market if the number of active firms is $f = n_F - i$; we omit writing out the latter, as it is found using the same procedure as in (A.12) - (A.14). Notice that $\gamma^* = 0$ if $\Psi_r(\lambda_H) < U_F^2(0, y)$, $\gamma^* = 1$ if $\Psi_r(\lambda_H) \geq U_F^2(0, y)$, and $\gamma^* \in (0, 1)$ solving $\Psi_r(\lambda_H) = U_F^2(0, y)$ otherwise.

With this in hand, we can now determine the behavior in stage 1. Denote the equilibrium expected utility in the public market of stage 2 conditional on y by $U_F^{2,\text{public}}(y)$. Similarly, denote the expected utility in stage 2 when attempting at hiring an H-type worker in stage 1 by $U_F^{2,\text{referral}}(y)$. The wage surely accepted by L-type workers $\bar{w}_1^1$ is exactly the same as in the Baseline, see (A.1). The maximum wage $\bar{w}_2^1 < \lambda_H$ a firm is willing to offer is different than in the *Baseline*, because of the valuable social links that come with hiring an H-type worker. It solves

$$u_F(P_L + B - \bar{w}_2^1) + U_F^{2,\text{public}}(\hat{n_F}) = \Psi(\lambda_H) + U_F^{2,\text{referral}}(\hat{n_F}) \tag{A.17}$$

where

$$U_F^{2,\text{referral}}(\hat{n_F}) = \mathbb{1}_{\Psi_r(\lambda_H)\geq U_F^{2,\text{public}}(\hat{n_F})}\left(\frac{n_L}{n_S}U_F^{2,\text{public}}(\hat{n_F}) + \frac{n_H}{n_S}\Psi_r(\lambda_H)\right) + \mathbb{1}_{\Psi_r(\lambda_H)<U_F^{2,\text{public}}(\hat{n_F})}U_F^{2,\text{public}}(\hat{n_F}). \tag{A.18}$$

The left-hand side of (A.17) is the sum of expected utilities over both stages when making low offers in both stages and all other firms offer $\{\lambda_H\}$ in stage 1 and follow the behavior derived above in stage 2. The right-hand side is the corresponding sum of expected utilities when making only a high offer in stage 1, hoping to hire a referral worker in stage 2.[27]

As in the *Baseline*, firms will mix between $\{\lambda_H\}$ and $\{\bar{w}_1^1, \lambda_H\}$. Let $\beta^{1,*}$ be the probability that firms offer $\{\lambda_H\}$. It is found by solving

$$\sum_{i=0}^{\hat{n}_F}(1-\beta^{1,*})^i(\beta^{1,*})^{\hat{n}_F-i}\binom{\hat{n}_F}{i}\left[U_F(\{\lambda_H\};i) + U_F^{2,\text{referral}}(\hat{n}_F-i) - \left(U_F(\{\bar{w}_1^1,\lambda_H\};i) + U_F^{2,\text{public}}(\hat{n}_F-i)\right)\right] = 0 \tag{A.19}$$

where $U_F(\{\lambda_H\};i)$ and $U_F(\{\bar{w}_1^1,\lambda_H\}$ have been derived in (A.4) and (A.6), respectively. If $\bar{w}_1^1 < \bar{w}_2^1$, $\beta^{1,*} = 1$. Notice that because $U_F^{2,\text{referral}}(\hat{n}_F - i) \geq U_F^{2,\text{public}}(\hat{n}_F - i)$, the probability $1-\beta^{1,*}$ to observe offers below λ_H is smaller in stage 1 of the *Referral* treatment than in the *Baseline* treatment. This completes the construction of the symmetric market equilibrium.

[27] The wage $\bar{w}_2^1$ is reached if all other firms offer $\{\lambda_H\}$, because this makes offering low more attractive in stage 1 and it also reduces the possible benefits from offering low in stage 2 because hiring an L-type becomes more likely (recall that when offering low a firm always includes a high offer as well, hoping that others will hire all L-types first).