Institute for Employment Research

The Research Institute of the Federal Employment Agency

IAB

Years

IAB-Discussion Paper 33/2017

Articles on labour market issues

Formal Search and Referrals from a Firm's Perspective

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ISSN 2195-2663

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Abstract

This study explores the relationship between firms' characteristics and their recruitment strategies. We propose a model based on a search and matching framework with two search channels: a formal channel which is costly for firms and a costless informal channel, i.e. referrals. There is a continuum of heterogeneous vacancies in our model where every firm with an open vacancy chooses an optimal search effort in order to attract job candidates. This search effort depends on the productivity of the firm and, contrary to the previous literature, workers send simultaneous applications to open vacancies. We assess the model predictions by using the IAB Job Vacancy Survey, a representative survey among human resource managers in Germany reporting information about their most recent recruitment case. Based on the finding that firm size and productivity are positively correlated we show that: (1) Larger firms invest more effort into formal search activities; (2) Firms invest more formal search effort in labour markets for more educated workers; (3) The positive relationship between firm's size and formal search intensity can also be observed for firms that don't use referrals; (4) Firms that use referrals as a search channel invest less effort into formal search compared to firms that don't use referrals; (5) Larger firms are less likely to hire an applicant by referral than smaller firms, and (6) More intensive search effort leads to a larger number of applications.

Zusammenfassung

Wir untersuchen den Zusammenhang zwischen den Merkmalen eines Betriebes und dessen Entscheidung für bestimmte Suchwege bei der Rekrutierung neuer Mitarbeiter. Wir konstruieren ein suchtheoretisches Modell, in dem Betriebe sich für eine oder mehrere Suchstrategien entscheiden können. Dabei unterscheiden wir formale Wege, die für die Unternehmen mit Kosten verbunden sind, und einen informalen Weg, der kostenlos ist und bei dem die Betriebe über Empfehlungen der beschäftigten Mitarbeiter suchen. In unserem Modell unterscheiden wir offene Stellen hinsichtlich ihrer Produktivität. Die Betriebe wählen einen bezüglich der zu erwarteten Kosten und Erträge optimalen Suchaufwand, um potentielle Bewerber für die offenen Stellen anzusprechen. Dabei können sich Arbeitsuchende gleichzeitig auf mehrere offene Stellen bewerben. Unsere Modell erlaubt eine Reihe von Vorhersagen zu Rekrutierungsstrategien der Betriebe bei der Suche nach Mitarbeitern. Diese Vorhersagen überprüfen wir mit Hilfe der IAB-Stellenerhebung, bei der Personalverantwortliche in Deutschland detailliert über ihren letzten Fall der Suche nach Mitarbeitern berichten. Wir zeigen, dass (1) größere Unternehmen eher in formale Suchwege investieren; dass (2) Unternehmen höheren formalen Suchaufwand in Arbeitsmärkten mit höher qualifizierten Arbeitskräften betreiben; dass (3) die positive Korrelation zwischen Unternehmensgröße und formaler Suchintensität auch für Unternehmen beobachtet werden kann, die nicht über Mitarbeiterempfehlungen suchen; dass (4) Unternehmen, die Mitarbeiterempfehlungen als Suchkanal benutzen, weniger Aufwand auf formalen Suchwegen betreiben als Unternehmen, die nicht über Mitarbeiterempfehlungen suchen; dass (5) größere Unternehmen mit einer geringeren Wahrscheinlichkeit einen Bewerber über Mitarbeiterempfehlungen einstellen als kleine Unternehmen; und schließlich dass (6) ein höherer Suchaufwand auf formalen Suchwegen zu einer größeren Anzahl an Bewerbungen führt.

JEL classification: J21, J23, J63, J64

Keywords: firm size, productivity heterogeneity, search effort, referrals, recruitment strategies

1 Introduction

There is a wide discussion in labor economics on strategies of job and worker search and their outcomes along the distinction of formal and referral search. The empirical literature suggests that both strategies are equally important, compare, e.g., with Topa (2011). Since the seminal work by Granovetter (1974) workers' choices of search strategies, particularly using social networks, were frequently analyzed. But there is only scarce literature that addresses firms' choices of search strategies.

Our paper explores the relationship between firms' characteristics and their recruitment strategies. We describe and evaluate a model of firm search with two search channels: a formal channel which is costly for firms and a costless informal channel. The formal search channel comprises different formal search strategies, which, beside others, include advertisements or the involvement of employment agencies, and the informal channel comprises recruitment by incumbent employees' referrals.

The scarce availability of data is the reason that only a few studies shed light on the motivation, reasons or outcomes of referrals relative to other search channels from the firms' perspective. Studies using personnel data include, e.g., Fernandez/Weinberg (1997), Fernandez/Castilla/Moore (2000), Castilla (2005), Fernandez/Sosa (2005) and Brown/Setren/Topa (2016). Even though these studies answer a broad range of questions regarding referrals, their analysis is either restricted to only one firm Castilla (2005), Fernandez/Sosa (2005), a selection of firms from certain regions (DeVaro, 2008), or branches (Fuller-Love, 2009; Berardi, 2013).

Due to the argument that formal search channels are more costly, it is plausible to think that more productive firms have larger resources which can be spend on formal search and stronger incentives to use these resources to attract job applicants. Thus, firm characteristics such as firm productivity or firm size are important for understanding firms' choices of recruiting channels, which is only possible by using a representative dataset on employers' recruitment strategies and processes.

To the best of our knowledge only Kramarz/Skans (2014) and Dustmann et al. (2016) used matched employer-employee data with firm characteristics to analyze referral hiring, however, none of the two studies reported results for the firm size.

From the theoretical perspective Galenianos (2013) is a most closely related study. It uses a search and matching framework with two search channels, formal and informal, and two firm types, where workers direct their job search to only one type of the firm. Even though this approach is plausible in a setting with two firm types it becomes restrictive when a continuum of heterogeneous firms is considered. Hence in this paper we extend and modify the theoretical approach of Galenianos (2013) to the more realistic case when workers send simultaneous applications to different firms and test our theoretical predictions by means of empirical data.

In our model workers are ex-ante homogeneous, while firms pay an entry cost and wait for the random productivity realisation. If productivity realisation is sufficiently high, firms enter the market and post vacancies. There are two channels of job search, a formal and an informal channel. Firms can choose their search intensity via the formal channel but this search effort is costly. Intuitively, these are the costs of posting a job advertisement in the newspaper, paying the registration fee on the internet job platform or paying for recruiting services of (private) employment agencies.

Endogenous formal search effort is introduced as in Pissarides (2000). Informal job search is based on employee referrals, here we use the framework of Cahuc/Fontaine (2009). The probability of an employee referral depends on the size of the social network and the equilibrium fraction of unemployed contacts in the networks of incumbent employees, however, it can not be influenced by firms.

In this framework we prove that more productive firms face larger foregone profits and invest more effort into formal search activities. This means that formal matching is balanced, that is workers are more likely to sample job ads from more productive firms. As a result more productive firms have a higher job-filling rate, which leads to a positive correlation between employment, productivity, wages and the fraction of workers hired via the formal channel. Therefore, larger firms do not only pay higher wages, which is a common "firm size effect" (see for example Burdett/Mortensen, 1998) but also have a smaller fraction of applicants hired by referrals.

We test this and other theoretical predictions by using IAB Job Vacancy Survey of the Institute for Employment Research (IAB JVS). The IAB JVS is a representative survey among human resource managers or managing directors in German firms reporting information about their search strategies with detailed answers about the most recent successful recruitment case and the most recent unsuccessful recruitment case. Since most firms are observed only once, our sample is a repeated cross-section of firms and includes more than 42,000 observations over the period 2012-2016.

The advantage of our empirical data is that we have detailed information about search activities of firms prior to hiring. Therefore, we do not only estimate an empirical link between the firm size and referral hiring but additionally control for the ex-ante search activities of firms, which is often unobserved in other datasets (e.g. labour force surveys) and considered an omitted variable. We summarize this ex-ante information in one intensity index, which is our empirical proxy for the formal search effort of firms. This search index is an ordinal variable equal to the number of formal search activities used by the firm. The list of such activities includes: placed ads in newspapers or magazines, posted vacancy in the internet, posted vacancy on the firm's own website, contacted the federal employment agency, contacted a private employment agency, and considered the pool of unsolicited applications. Because of the ordinal nature of this index variable we use an ordinal logistic regression with time-fixed effects to predict which firms are using these formal search strategies more intensively.

We find that larger firms use more often formal search activities to find applicants. Moreover, this positive link between the firm size and the formal search index is observed regardless of the fact whether the firm is using referrals or not, but the formal search index is lower on average if employee referrals are used. These empirical findings are inline with our theoretical predictions.

Even though we consider a submarket with homogeneous workers in our model, we can perform comparative statics with respect to the workers' skill level. This analysis reveals that firms exert more formal search effort in submarkets with higher worker skills. This prediction is also supported by our empirical analysis. We find that the formal search index is higher for positions requiring vocational training and even higher for positions requiring a university degree.

A broad set of firm and vacancy specific control variables are considered and a number of robustness checks corroborate our results. One of them is based on using monetary expenses of firms for recruitment processes which can be seen as another proxy for the search effort of firms.

Our paper is related to a number of theoretical and empirical studies on referrals as search strategy. The seminal contribution in this field was by Montgomery (1991). He shows that employee referrals may serve as a useful screening device if worker's ability is not observed by the potential employer. Hensvik/Skans (2016) confirm this result empirically by using Swedish data.

Further purely theoretical studies on referrals can be generally divided into two groups, those using network theory (Ioannides/Soetevent, 2006; Calvo-Armengol/Jackson, 2004, 2007; Horvath, 2014) and those using search and matching framework (Fontaine, 2008; Cahuc/Fontaine, 2009; Zaharieva, 2013, 2015; Stupnytska/Zaharieva, 2015). Whereas the first group of studies shows that exchange of job information within the network of friends leads to better employment chances, the second group of studies has a stronger focus on worker and firm heterogeneity.

For example, Fontaine (2008) shows that heterogeneity in the size of social networks leads to different bargaining positions of workers and generates wage dispersion. Similar to our study, Zaharieva (2015) considers a model with heterogeneous firms and identical workers. In this model workers continue searching on-the-job and accept job offers from more productive firms while forwarding offers from less productive firms to their social contacts. Thus, referral job offers are associated with a wage penalty compared with the formal channel.

Empirical studies using personnel data (Simon/Warner, 1992; Castilla, 2005; Fernandez/Sosa, 2005; Brown/Setren/Topa, 2016) typically report that workers who apply due to a referral are more likely to be invited for the interview than workers that apply via the formal channel. These studies also find that workers hired due to referrals receive a slight wage premium over workers that were hired via the formal channel, even though this premium disappears over time. On the other hand, panel data studies based on worker surveys report wage penalties associated with referrals (Pistaferri, 1999; Addison/Portugal, 2002). Pellizzari (2010) concludes that in the European Union premiums and penalties to finding jobs through personal contacts are equally frequent and are of about the same size.

Other studies contain both empirical and theoretical analysis of referral hiring. Similar to our study, Kugler (2003) considers the problem from the perspective of firms and finds that referred workers are more productive because of the peer pressure and internal monitoring by the incumbent employee who provided recommendation. This mechanism leads to lower monitoring costs for firms that rely on referral hiring and stimulates firms to pay efficiency wages. Galeotti/Merlino (2003) consider workers' search via networks over the business cycle and show that the search intensity is characterised by the inverse U-shape, that is workers initially increase their search effort in the recession but get discouraged later on if the recession gets more severe. Bentolila/Michelacci/Suarez (2010) develop a model that can explain wage penalties associated with referrals by linking referral hiring and occupational mismatch. Specifically, in their model unemployed workers may follow the recommendation of friends and relatives and accept mismatch jobs in alternative occupations.

Our study is also close to the early search literature on wages, productivities and firm sizes with the seminal contribution by Burdett/Mortensen (1998) who show that firms offering higher wages are able to attract and keep more workers, resulting in a positive link between wages and firm sizes. Bontemps/Robin/van den Berg (2000) complement this model with heterogeneous firms and show a positive correlation between productivities, wages and firm sizes. Both studies are based on the assumption of random matching, which means that all firms have an equal probability of being sampled by workers independent of their size.

Though the finding of a positive correlation between productivities, wages and firm sizes is corroborated by our model, it is nevertheless different, because in our model larger firms invest more search effort and are more likely to be matched with workers compared to smaller firms. In this respect our study continues the balanced matching approach of Burdett/Vishwanath (1988) with the difference that positive association between the matching rate and firm size is endogenous in our model, while it is assumed to be exogenous in Burdett/Vishwanath (1988).

Even more closely related is the study by Mortensen/Vishwanath (1994), who introduce two sampling distributions. Specifically, in their model workers are randomly matched to firms via the formal search channel but can also be matched with a help of incumbent employees, which yields a superior distribution of wage offers. Therefore, referral matching is balanced and workers are more likely to be matched to jobs offering higher wages than jobs with lower wages. Despite this similarity our model is different from Mortensen/Vishwanath (1994) because firms have different productivities and there is an explicit choice of search intensity by firms in our setting.

In contrast to our model Postel-Vinay/Robin (2002) do not consider referral hiring in their model, but they also allow for endogenous hiring effort of heterogeneous firms. The unusual feature of their model is that this hiring effort is not specified, so it can be increasing or decreasing with the firm's size. However, if a convex hiring cost is assumed, their model implies a negative relationship between the firm size and hiring effort. Empirically, by using French labour market data, they find a non-monotonic relationship between the firm size and hiring effort. Thus, these results are different from our findings.

The plan of the paper is as follows. Section 2 presents our theoretical model with a number of testable predictions. Section 3 describes the data sample. Section 4 contains our empirical results. Section 5 presents additional robustness checks and section 6 concludes.

2 Theoretical framework

2.1 Labour market framework

The labour market is characterized by the following properties. There is a continuum of infinitely lived risk neutral workers and firms discounting future at a common discount rate r. When entering the market every firm has to pay an entry cost K. Firms are ex-ante homogeneous when they enter the market and join the pool of vacancies v_0. At the Poisson arrival rate γ firms receive a firm specific productivity level p randomly drawn from the exogenous productivity distribution $F(p)$, with the corresponding density $f(p)$[1]. To keep the model tractable we assume that the productivity distribution is uniform, so that $F(p) = p$, $p \in [0..1]$. The firm can either accept the type p and post an open vacancy $v(p)$ or reject the type and continue waiting for another productivity draw. Let p_0 denote the endogenous reservation productivity of firms. Thus firms accept productivity realizations above p_0 and reject otherwise. This mechanism is illustrated in figure 1 and generates ex-post heterogeneity of vacancies $v(p)$ for $p_0 < p < 1$[2]. Open vacancies can be either filled with the worker or abandoned without hiring, which happens at rate ϕ. Abandoned vacancies exit the market.

Even though our model builds on the seminal contribution by Mortensen/Pissarides (1994), heterogeneous productivities are generated in a different way. In Mortensen/Pissarides (1994) vacancies are identical before matching and productivity draws are realised after the worker and the firm are matched. Thus heterogeneous productivities are an outcome of different match qualities and it is not specified whether it is because the worker is more productive or the firm. This is different in our setting, where vacancies are heterogeneous already before matching, thus higher productivity is fully attributable to the firm. This property is important for our empirical analysis where we can fully exploit rich firm characteristics contained in our data.

Workers are ex-ante homogeneous and contribute part b to the total output. This means that any worker matched with a firm of type p produces output bp, where b is the contribution of the worker and p is the contribution of the firm. Even though all workers are identical in the considered labour market, changing b in the form of comparative statics will allow us to analyze the implications of the model for labour markets with more educated workers (higher b) or workers with lower qualification (lower b). Note also that more educated workers are more productive. Employed workers receive the wage $w(p)$, which is obtained by Nash bargaining between the worker and the firm. Worker's bargaining power is denoted by β and the reservation wage is $\bar{w} < b$. Even though we keep $\bar{w}$ constant and

[1] Later we will show that the firm's productivity p is positively correlated with the employment share, which is our proxy for the firm size.

[2] Intuitively, one could think of the cost K as a cost of conducting a demand survey for the new product, where the survey results are delivered after a random period of time. If the survey reveals high demand in the future, that is $p > p_0$, the firm enters the market and posts an open vacancy.

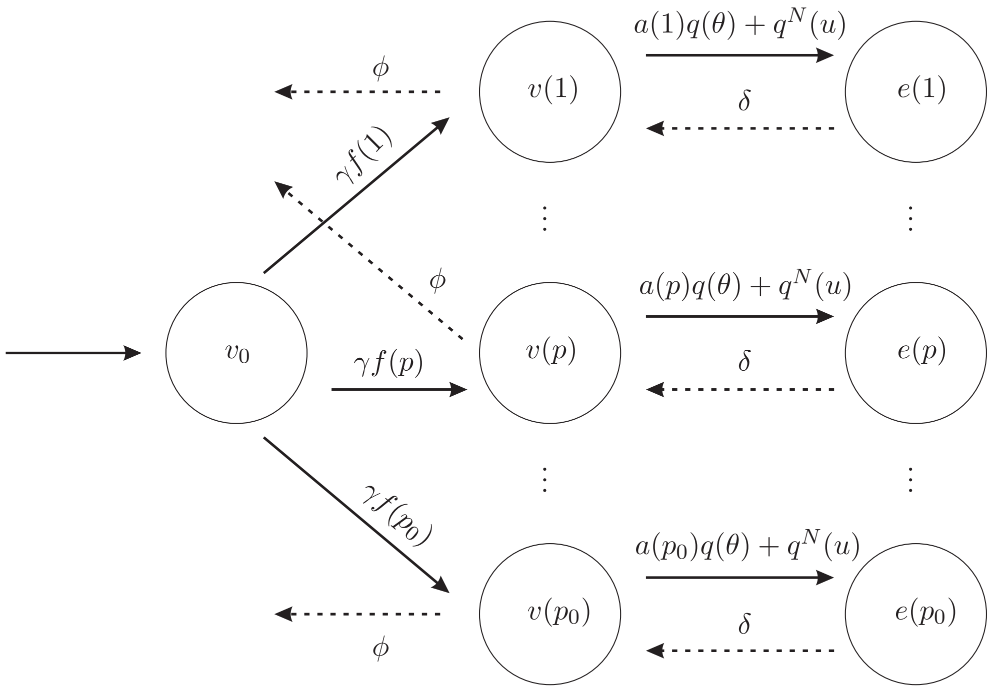

Figure 1: Labour market dynamics

Source: own research

exogenous throughout the model, in the appendix we show how it can be endogenized. All filled jobs can be destroyed at rate δ. After the job destruction shock the worker becomes unemployed and the firm returns to the pool of vacancies $v(p)$ depending on it's type p.

Firms can hire workers via the formal search channel or via referrals from incumbent employees. We model referral search as Cahuc/Fontaine (2009). Let every worker have l social contacts. The firm sends its vacancy to one randomly chosen person in the population. This person is unemployed with probability u and employed with probability $1 - u$. Unemployed workers always accept the job offer (formal proof is provided in the next section). Since there is no on-the-job search, employed workers can not make use of the open vacancy and consider their social network. With probability $(1 - u)^l$ all their social contacts are already employed, but with probability $1 - (1 - u)^l$ the employee has at least one unemployed friend in the social network. So the offer is then forwarded to this friend. Thus the network job-filling rate q^N is given by:

$$q^N(u) = s(u + (1 - u)(1 - (1 - u)^l)) = s(1 - (1 - u)^{l+1})$$

where s is an indicator variable taking value 1 in the equilibrium with referral hiring and 0 otherwise. This variable is helpful in distinguishing between the two settings with and without referrals. Above equation shows that $q^N(u)$ is an increasing function of u. Intuitively, this means that higher unemployment raises the probability that incumbent employees recommend one of their friends for the job and the position is filled by referral.

Next we consider the formal search channel. Let $a(p)$ be the formal search intensity of type p vacancies. Then $a(p)v(p)$ denotes efficiency units of these vacancies (see Pissarides,

2000) with total efficiency units of all vacancies in the market given by:

$$\tilde{v} = \int_{0}^{1} a(p)v(p)dp$$

We assume that formal search effort is costly for firms with the corresponding quadratic cost function $c(a) = a^2/(2c_0)$. We further assume that referral hiring is free of cost for firms. Cahuc/Fontaine (2009) and Stupnytska/Zaharieva (2017) made similar assumptions. Galenianos (2013), on the contrary, assumes that referrals are more costly for firms than formal hiring.

Matching via the formal channel is achieved by means of a standard matching function $m(u, \tilde{v})$, which is increasing in both arguments and homogeneous of degree 1. Thus $m(u, \tilde{v})$ is the total number of matches between searching unemployed workers and open vacancies created via the formal channel per period of time. Let $\theta = \tilde{v}/u$ denote the market tightness. The number of formal matches between unemployed workers and type p vacancies is given by:

$$m(u, \tilde{v})\frac{a(p)v(p)}{\tilde{v}}$$

Consider some firm j of type p with the search intensity a_j, so the probability of being matched with the worker via the formal channel for this firm is given by:

$$m(u, \tilde{v})\frac{a(p)v(p)}{\tilde{v}}\frac{a_j}{a(p)v(p)} = a_j\frac{m(u, \tilde{v})}{\tilde{v}} = a_j m(\frac{1}{\theta}, 1)$$

Let $q(\theta) \equiv \frac{m(u,\tilde{v})}{\tilde{v}}$, so the flow probability of being matched for firm j is equal to $a_j q(\theta)$. This means that higher search effort a_j raises the probability of hiring a worker. At the same time, a larger θ reduces this probability. This can be either because the number of unemployed workers is smaller or because all other vacancies are searching more intensively. Since every firm can use both search channels simultaneously the total job-filling rate for firm j is given by: $a_j q(\theta) + q^N(u)$, see figure 1.

2.2 Choice of the formal search intensity

Let $V(p)$ be the present value of an open vacancy and $J(p)$ be the present value of a filled job for a firm of type p. Consider some firm j of type p with the present value of an open vacancy $V_j(p)$ given by:

$$rV_j(p) = -c(a_j) + (a_j q(\theta) + q^N(u))(J(p) - V_j(p)) - \phi V_j(p) \tag{1}$$

where $a_j q(\theta)$ is the job-filling rate through the formal search channel and $q^N(u)$ is the job-filling rate through the network of social contacts. So that $a_j q(\theta)+q^N(u)$ is the total job-filling rate of firm j and $c(a_j)$ are the costs of using the formal channel. At rate ϕ the firm exits the market (bankruptcy) before the position is filled. The firm chooses its formal search intensity a_j to maximize the present value of an open vacancy $V_j(p)$, which yields the following first order condition:

$$c'(a_j) = q(\theta)(J(p) - V_j(p))$$

which means that the marginal cost of higher search effort $c'(a_j)$ should be equal to the marginal gain $q(\theta)(J(p) - V_j(p))$. With a quadratic cost function $c(a_j) = a_j^2/(2c_0)$ the optimal search intensity of firm j is given by:

$$a_j(p) = c_0 q(\theta)(J(p) - V_j(p))$$

This means that the optimal search effort of firm j is increasing in the expected net gain from filling the job with the worker $(J(p) - V_j(p))$. In the equilibrium all firms of type p will choose the same search effort, so that $a_j(p) = a(p)\ \forall j$. Insert the optimal $a(p)$ into equation (1) to get:

$$(r + \phi)V(p) = 0.5c_0 q^2(\theta)(J(p) - V(p))^2 + q^N(u)(J(p) - V(p)) \tag{2}$$

Next consider the present value of a filled job $J(p)$, which can be written as:

$$rJ(p) = bp - w(p) - \delta(J(p) - V(p)) \quad \Rightarrow \quad J(p) - V(p) = \frac{bp - rV(p) - w(p)}{r + \delta}$$

where $w(p)$ is the wage and $bp - w(p)$ is the firm's flow profit. At rate δ the worker and the firm separate and the firm starts searching for a new worker, which yields the present value $V(p)$. Further recall that $\bar{w}$ denotes the reservation wage of the worker and β is the bargaining power. Nash bargaining between the firm and the worker can be written as:

$$\max_{w(p)} (w(p) - \bar{w})^\beta (bp - rV(p) - w(p))^{1-\beta}$$

The first order condition yields the wage $w(p)$:

$$w(p) = \beta(bp - rV(p)) + (1 - \beta)\bar{w}$$

Later we will show that the term $bp - rV(p)$ is increasing in the productivity p, therefore our wage equation indicates that more productive firms pay higher wages. Insert this wage equation into the firm rent $J(p) - V(p)$ to get:

$$J(p) - V(p) = (1 - \beta)\frac{bp - rV(p) - \bar{w}}{r + \delta}$$

To simplify the notation let $y(p) \equiv bp - \bar{w}$ denote the net flow output and insert the firm's rent $J(p) - V(p)$ into the equilibrium equation (2):

$$(r + \phi)V(p) = 0.5c_0 q^2(\theta)(1 - \beta)^2 \frac{(y(p) - rV(p))^2}{(r + \delta)^2} + q^N(u)(1 - \beta)\frac{(y(p) - rV(p))}{(r + \delta)} \tag{3}$$

This is a quadratic equation in $V(p)$ which can be rewritten as:

$$A(\theta)r^2 V^2(p) - V(p)[2rA(\theta)y(p) + rB(u) + r + \phi] + A(\theta)y^2(p) + B(u)y(p) = 0 \tag{4}$$

$$\text{where} \qquad A(\theta) \equiv \frac{c_0 q^2(\theta)(1-\beta)^2}{2(r+\delta)^2} \qquad B(u) \equiv \frac{q^N(u)(1-\beta)}{(r+\delta)}$$

Solution of this quadratic equation is given by:

$$rV(p) = y(p) - \frac{1}{2A(\theta)r}\Big(\sqrt{(rB(u)+r+\phi)^2 + 4rA(\theta)y(p)(r+\phi)} - (rB(u)+r+\phi)\Big)$$

Proposition 1: *The present value of an open vacancy $V(p)$ is increasing in the net output $y(p)$ and in the auxiliary variables $A(\theta)$ and $B(u)$. This means that $V(p)$ is increasing in $q(\theta)$ and $q^N(u)$. Moreover, $\lim_{\theta\to 0} rV(p) = y(p)$.* **Proof:** Appendix I.

This proposition and the above equation for $rV(p)$ imply that more productive firms expect to get a higher present value of profits in the future. At the same time this present value is increasing in the job-filling rates $q(\theta)$ and $q^N(u)$. The easier it is to hire workers, the higher is the expected present value of profits. At the same time, note that $V(p)$ is increasing in u but decreasing in θ because $q'(\theta) < 0$. If unemployment u is higher it is easier for firms to hire workers by referrals. On the other hand, a higher market tightness θ implies more competition among vacancies and reduces firms' hiring chances. Note also that $y(p)-rV(p)$ is increasing in p, which proves that more productive firms pay higher wages.

Our last result in proposition 1 concerns the case when θ is converging to 0. This is the limiting case when search frictions become negligible because $q(\theta) \to \infty$. In this situation firms can hire workers immediately, so $V(p) = y(p)/r = (bp - \bar{w})/r$, which means that workers receive their reservation wage $\bar{w}$ and do not have any effective bargaining power.

Our findings concerning the optimal search intensity $a(p)$ are summarized in proposition 2:
Proposition 2: *The optimal search intensity in the formal market $a(p)$ is given by:*

$$a(p) \quad = \quad \frac{r+\delta}{rq(\theta)(1-\beta)}\Big(\sqrt{(rB(u)+r+\phi)^2 + 4rA(\theta)y(p)(r+\phi)} - (rB(u)+r+\phi)\Big)$$

$a(p)$ is increasing in the net output $y(p)$. It is also increasing in $q(\theta)$ but decreasing in $q^N(u)$.
Proof: Appendix II.

Proposition 2 shows our main results. Namely, more productive firms exert more formal search effort. This is because more productive firms face higher foregone income if the position is not filled, so their incentives to search formally are stronger. At the same time our model predicts that $a(p)$ is decreasing in $q^N(u)$. This shows substitution between the two channels. Firms reduce their search effort if hiring by referrals becomes easier. On the other hand $a(p)$ is increasing in $q(\theta)$. This means, if formal channels are more efficient, they become more attractive to firms, and lead to more search effort $a(p)$.

This section shows that the present value of an open vacancy $V(p)$ not only depends on the firm type p, but it also depends on the equilibrium situation in the labour market summarized by variables $\{\theta, u\}$. So in the following to capture this relationship we will use notation $V(p,\theta,u)$, where it is increasing in p and u but decreasing in the market tightness θ.

2.3 Free-entry of firms

Let V denote the discounted present value of profits for firms expecting their type p to be assigned (present value of waiting), which is given by:

$$rV = \gamma \int_0^1 \max(V(p,\theta,u) - V, 0)dF(p)$$

This equation shows that the firm can reject low realizations of p and continue waiting. So the firm accepts a productivity realization only if $V(p,\theta,u) \geq V$. We know from above that $V(p,\theta,u)$ is increasing in the firm type p. Further recall, that p_0 denotes the lowest acceptable realization of p, so that $V(p_0,\theta,u) = V$. This yields:

$$rV = \gamma \int_{p_0}^1 (V(p,\theta,u) - V)dF(p)$$

Rewrite this integral by using the substitution $y = bp - \bar{w}$, the fact that $F(p) = p$ due to the simplifying assumption of a uniform distribution and $dy = bdp$:

$$rV = \frac{\gamma}{b} \int_{y_0}^{b-\bar{w}} (V(y,\theta,u) - V)dy$$

where $y_0 = bp_0 - \bar{w}$ is the lowest acceptable net output from the perspective of firms. Free-entry implies that firms enter the market as long as it is profitable for them, i.e. $V > K$. So in the equilibrium we should have $K = V$, which also means $K = V(y_0,\theta,u)$. So the first equilibrium equation between variables y_0 and θ (for given u) becomes:

$$rK = \frac{\gamma}{b} \int_{y_0}^{b-\bar{w}} (V(y,\theta,u) - K)dy \qquad \Rightarrow \qquad \theta(y_0,u) \tag{5}$$

The right-hand side of this equation is an expected present value of firm profits after entry, which takes into account the option value from rejecting low productivity realizations. The left-hand side is the cost of entry. To guarantee that the function below the integral takes positive values at least for some productivities we assume that the entry-cost K is not too large, that is $rK < b - \bar{w}$. Next consider the slope of this curve denoted by $d\theta(y_0,u)/dy_0$:

$$\frac{d\theta(y_0,u)}{dy_0} = \frac{(V(y_0,\theta,u) - K)}{\int_{y_0}^{b-\bar{w}} \frac{\partial V(y,\theta,u)}{\partial \theta} dy} \qquad \begin{cases} > 0 & \text{if} \quad V(y_0,\theta,u) < K \\ = 0 & \text{if} \quad V(y_0,\theta,u) = K \\ < 0 & \text{if} \quad V(y_0,\theta,u) > K \end{cases}$$

Formally, this means that the curve $\theta(y_0,u)$ is increasing up to the intersection with the curve $V(y_0,\theta,u) = K$, where it achieves a maximum, and decreasing thereafter (for fixed u). Recall that V is the discounted present value of profits for firms expecting their type p to be assigned. Setting $V = K$ implies that we consider the iso-profit curve of firms, which is also their indifference curve. Equation (5) shows that firms achieve maximal profits when they choose y_0 so that $V(y_0,\theta,u) = K$. A lower value of y_0 reduces the profits of firms because firms accept suboptimally low productivity levels. On the other hand, choosing y_0 which is too high would imply that firms reject good opportunities in terms of profits. Thus it is intuitive that expected profits of firms are maximized at the point $V(y_0,\theta,u) = K$ (see figure 2).

Next we should analyze the functional relationship implied by the second equilibrium condition $V(y_0, \theta, u) = K$, which can be rewritten as (based on equation (4)):

$$A(\theta)r^2K^2 - K(2rA(\theta)y_0 + rB(u) + r + \phi) + A(\theta)y_0^2 + B(u)y_0 = 0$$

This is a quadratic equation in y_0, its solution and properties are summarized in proposition 3:

Proposition 3: *The optimal threshold productivity of firms y_0 is given by*

$$y_0(\theta, u) \quad = \quad rK + \frac{(r+\delta)}{c_0 q^2(\theta)(1-\beta)}\Big(\sqrt{(q^N(u))^2 + 2c_0 q^2(\theta)K(r+\phi)} - q^N(u)\Big)\Big(> rK \qquad (6)$$

This function is strictly decreasing in $q(\theta)$ and $B(u)$, which means that $y_0(\theta, u)$ is increasing in θ but decreasing in u. Moreover, $\lim_{\theta\to 0} y_0(\theta, u) = rK$. **Proof:** Appendix III.

Proposition 3 shows that the net threshold productivity $y_0(\theta, u)$ is decreasing in $q(\theta)$, that is increasing in θ. It means that a higher value of the market tightness makes it more difficult for firms to hire workers and has a negative impact on the present value of an open vacancy $V(y_0, \theta, u)$. As a response to this firms optimally raise their threshold productivity y_0 and become choosier with respect to which productivity values they accept. This generates a positive link between θ and y_0. Moreover, if $\theta \to 0$ ($A(\theta) \to \infty$), search frictions disappear, thus firms accept any productivity that just covers their cost of entry rK. So the curve $y_0(\theta, u)$ is increasing in θ starting at the point $\{\theta = 0, y_0 = rK\}$. This is also illustrated on the left panel of figure 2. This figure shows that the two curves $\theta(y_0, u)$ and $y_0(\theta, u)$ intersect only once for a given value of u. To show this formally recall that $rV(y, \theta, u) \to y$, so that equation (5) becomes:

$$rK = \frac{\gamma}{br}\int_{y_0}^{b-\bar{w}} (y - rK)dy = \frac{\gamma}{br} 0.5\Big((b - \bar{w} - rK)^2 - (y_0 - rK)^2\Big) \qquad (7)$$

This is a quadratic equation in y_0 with the corresponding roots (proof in appendix IV):

$$y_0^{(1)} = rK - \sqrt{(b - \bar{w} - rK)^2 - \frac{2r^2bK}{\gamma}} < rK \qquad y_0^{(2)} = rK + \sqrt{(b - \bar{w} - rK)^2 - \frac{2r^2bK}{\gamma}} > rK$$

Assuming that $\gamma > 2r^2bK/(b - \bar{w} - rK)^2$, we find that one root of this equation is below rK and the other one is above rK. So the system of equations $y_0(\theta, u)$ and $\theta(y_0, u)$ (defined by equations (5) and (6)) produces unique values of variables $y_0^*(u)$ and $\theta^*(u)$ for any given unemployment rate u (see the left panel of figure 2).

These results are important from the economic perspective. In particular, the fact that $y_0^*(u) > rK$ implies that all workers optimally accept all jobs in this economy. To see this, note that $y_0^*(u) > rK$ is equivalent to:

$$bp_0 - \bar{w} > rV(bp_0 - \bar{w}) \Leftrightarrow bp_0 - rV(bp_0 - \bar{w}) > \bar{w} \Leftrightarrow w(p_0) > \bar{w}$$

which means that even the least productive firms in the market are able to pay the wage which is higher than the reservation wage of workers. Thus it is always optimal for workers to accept all jobs. Intuitively, this is because firms pay an entry cost K in this market, which

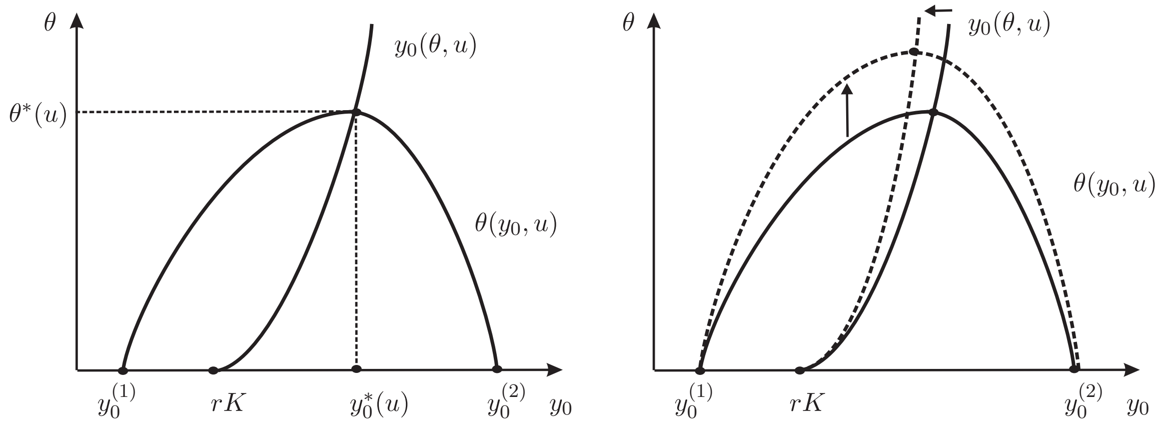

Figure 2: Partial equilibrium for a given u

Source: own research.

makes them relatively selective, so the threshold productivity p_0 (and also y_0) is sufficiently high. In other words, unproductive firms that can not even pay the reservation wage to workers don't enter the market. In appendix V we show how the reservation wage can be derived endogenously in our model.

Next consider changes in the unemployment rate u. For higher values of u the curve $y_0(\theta, u)$ shifts to the left for any positive θ. If the unemployment rate is higher it becomes easier for firms to hire workers by referrals, which leads to the higher present value of open vacancies $V(y, \theta, u)$. This makes firms less choosy in terms of accepted productivity levels and implies a lower threshold y_0 for every market tightness θ. The corresponding curve $y_0(\theta, u)$ shifts to the left on the right panel of figure 2.

To see the shift of the other curve $\theta(y_0, u)$ we derive:

$$\frac{d\theta(y_0,u)}{du} = -\frac{\int_{y_0}^{b-\bar{w}} \frac{\partial V(y,\theta,u)}{\partial u} dy}{\int_{y_0}^{b-\bar{w}} \frac{\partial V(y,\theta,u)}{\partial \theta} dy} > 0$$

This means that the curve $\theta(y_0, u)$ shifts upwards for every value of y_0 except the two intersection points with the horizontal axis $y_0^{(1)}$ and $y_0^{(2)}$. Economically, this means that easier hiring via networks makes firms better off and leads to higher expected profits. However, free-entry implies that expected profits of firms are fixed and equal to the cost of entry K. For fixed y_0 this is only possible if the market tightness θ is increased making it more difficult for firms to hire workers via the formal channel. This illustrates substitution between the two recruitment channels. Consequently, $\theta^*(u)$ is unambiguously increasing in u but the change in $y_0^*(u)$ is ambiguous and can be positive or negative.

2.4 Equilibrium unemployment and vacancies

In this section we close the model and determine the equilibrium values of unemployment and vacancies. Let v denote the total number of open vacancies in the equilibrium, that is $v = \int_{p_0}^{1} v(p)dp$. Considering networks, every open position is filled at rate $q^N(u) = s(1 -$

$(1-u)^{l+1})$, which implies that the total number of matches via the network is given by $sv(1-(1-u)^{l+1})$ in every period of time. The total number of matches via the formal channel is equal to $m(u,\tilde{v}) = um(1,\theta)$. So the total number of individuals finding jobs in a given period of time is a sum: $um(1,\theta) + sv(1-(1-u)^{l+1})$. At the same time jobs can be destroyed at rate δ, so that $\delta(1-u)$ is an average number of workers losing jobs. In the steady state it should be that the inflow of workers into unemployment is equal to the outflow:

$$um(1,\theta) + sv(1-(1-u)^{l+1}) = \delta(1-u)$$

Inserting $\theta^*(u)$ from the previous section, we obtain a modified version of the Beveridge curve which describes a negative relationship between unemployment u and vacancies v:

$$v = \frac{\delta(1-u) - um(1,\theta^*(u))}{s(1-(1-u)^{l+1})} \tag{8}$$

Finally, the definition of the market tightness θ implies:

$$\theta = \frac{\tilde{v}}{u} = \frac{1}{u}\int_{p_0}^{1} a(p)v(p)dp = \frac{v}{u}\int_{p_0}^{1} a(p)\frac{v(p)}{v}dp \tag{9}$$

Recall that v_0 is a number of vacancies waiting for their type to be assigned, so that $\gamma v_0 f(p)$ is a number of vacancies receiving type p per unit time (see figure 1). These vacancies are matched with workers at rate $a(p)q(\theta) + q^N(u)$. At the same time, these vacancies can be destroyed and exit the market at rate ϕ. This gives rise to the system of dynamic equations for $v(p)$ and $e(p)$:

$$\begin{aligned}\dot{v}(p) &= \gamma v_0 f(p) + \delta e(p) - (a(p)q(\theta) + q^N(u))v(p) - \phi v(p)\\ \dot{e}(p) &= (a(p)q(\theta) + q^N(u))v(p) - \delta e(p)\end{aligned}$$

In the steady state it should be the case that $\dot{v}(p) = 0$ and $\dot{e}(p) = 0\ \forall p$. Combining the two equations above this means that $v(p) = \gamma v_0 f(p)/\phi$ and:

$$v = \int_{p_0}^{1} v(p)dp = \int_{p_0}^{1} \frac{\gamma v_0}{\phi} f(p)dp = \frac{\gamma v_0}{\phi}(1-F(p_0))$$

so the distribution of vacancies is $v(p)/v = f(p)/(1-F(p_0))$. With the uniform distribution equation (9) can be written as:

$$v = \frac{\theta^*(u)u}{\bar{a}(u)} \quad \text{where} \quad \bar{a}(u) \equiv \int_{p_0}^{1} a(p)\frac{v(p)}{v}dp = \int_{p_0}^{1}\frac{a(p)f(p)}{(1-F(p_0))}dp = \int_{y_0^*(u)}^{b-\bar{w}} \frac{a(y,u)}{b-(y_0^*(u)+\bar{w})}dy$$

Note that $\bar{a}(u)$ is the average formal search intensity in the market. From proposition 2 we know that $a(p)$ is decreasing in the unemployment rate u. This is because more unemployed workers make it easier for firms to hire workers by referrals, and so firms reduce their formal search effort $a(p)$. So if the shift in the threshold productivity $y_0^*(u)$ is not very pronounced, this generally has a negative impact on the average formal search intensity $\bar{a}(u)$. Equation (9) implies then a positive link between unemployment and vacancies $v = u\theta^*(u)/\bar{a}(u)$. The equilibrium unemployment is then obtained at the intersection between the modified Beveridge curve and the curve $v = u\theta^*(u)/\bar{a}(u)$ (equations (8) and (9)). These results are summarized in proposition 4:

Proposition 4: *Let $\gamma > 2r^2bK/(b - \bar{w} - rK)^2$. If the average formal search intensity $\bar{a}(u)$ is decreasing in u, then there exists a unique equilibrium with the unemployment rate u given by the following equation:*

$$\frac{\delta(1-u) - um(1,\theta(u))}{s(1-(1-u)^{l+1})} = \frac{\theta^*(u)u}{\bar{a}(u)}$$

The equilibrium number of vacancies is $v = \theta^*(u)u/\bar{a}(u)$. The market tightness $\theta^*(u)$ and the threshold productivity $y_0^*(u)$ are given by equations (5) and (6).

This proposition shows that there are two conditions which are sufficient for the existence of the unique equilibrium in our model. The first condition is $\gamma > 2r^2bK/(b - \bar{w} - rK)^2$, which means that productivity draws should arrive sufficiently often to firms, so that firms can recover their ex-ante entry cost K. In addition, it should be the case that the average formal search intensity $\bar{a}(u)$ is decreasing in u. This condition is likely to hold numerically, because all firms reduce their formal search intensity $a(y,u)$ in response to higher u and the productivity threshold $y_0^*(u)$ is not sensitive to changes in the unemployment rate u (see the right panel of figure 2). Next we turn to summarizing a number of empirically testable predictions based on our model.

2.5 Summary of model predictions

In this section we summarize several testable predictions from our model. To arrive at these predictions first we derive the distribution of workers across jobs in our labour market $e(p)/e$. From the differential equation for $\dot{e}(p)$ (in the steady state) we get that the measure of workers employed in jobs with productivity p is given by:

$$e(p) = \frac{1}{\delta}[a(p)q(\theta) + q^N(u)]v(p)$$

By integrating this measure over all firms we can find the total equilibrium employment e:

$$e \quad = \quad \frac{1}{\delta}\int_{p_0}^{1}[a(p)q(\theta) + q^N(u)]v(p)dp = \frac{1}{\delta}[(q(\theta)\bar{a}(u) + q^N(u)]v$$

Dividing $e(p)$ by e we get the distribution of workers across firms:

$$\frac{e(p)}{e} = \frac{a(p)q(\theta) + q^N(u)}{\bar{a}(u)q(\theta) + q^N(u)} \cdot \frac{v(p)}{v} = \frac{a(p)q(\theta) + q^N(u)}{\bar{a}(u)q(\theta) + q^N(u)} \cdot \frac{b}{b - (y_0^*(u) + \bar{w})}$$

This equation shows the following: in the special case of our model when formal search intensity is fixed at a, the distribution of workers across firms would coincide with the distribution of vacancies $v(p)/v$. But when formal search intensity is endogenous than $a(p)$ is increasing in the productivity p, so the distribution of workers across firms has an increasing density $e(p)/e$. This means that more productive firms exert more search effort via the formal channel and can hire more workers.

On the contrary, less productive firms don't find it very profitable to invest into formal search and rely stronger on referral hiring. This means that relatively many workers are employed in more productive firms and receive high wages and relatively few workers are employed in less productive firms. Formally, we get $e(p)/e > v(p)/v$ if $a(p) > \bar{a}(u)$.

Economically, this means that there is a positive association between the firm size and the productivity p. Even though firm size is generally not defined in search models this association was already mentioned by other authors, e.g. Burdett/Mortensen (1998). So for the purpose of generating testable model predictions we will interpret variable p not only as productivity but also as a firm size.

Given this interpretation of the model and the fact that $a(p)$ is increasing in $y(p)$ (proposition 2), we find that larger firms face higher foregone income from their open positions and have stronger incentives to invest more into formal search. This allows us to formulate the first hypothesis:

Hypothesis H1: *Larger firms invest more effort into formal search activities than smaller ones, that is* $\partial a(p)/\partial p > 0$.

Next notice that firm's productivity $y(p) = bp - \bar{w}$ not only depends on the firm's type p but it also depends on the type of the worker b. That is firms face even higher foregone income in labour markets for more educated workers, so they invest more into formal job search in these markets. We summarize this finding in hypothesis H2:

Hypothesis H2: *Firms invest more formal search effort in labour markets for more educated workers, that is* $\partial a(p)/\partial b > 0$.

Suppose now that some firms don't use referrals as a search channel, that is $s = 0$. Their search intensity via the formal search channel then becomes:

$$a(p) = \frac{r+\delta}{rq(\theta)(1-\beta)}\left(\sqrt{(r+\phi)^2 + 4rA(\theta)y(p)(r+\phi)} - (r+\phi)\right)$$

which means that even if referrals are not used by firms there is still a positive relationship between firm size and formal search intensity. We formulate this prediction in hypothesis H3:

Hypothesis H3: *The positive relationship between firm size and formal search intensity should be observed even for firms that don't use referrals, that is* $\partial a(p)/\partial p > 0$ *even if* $s = 0$.

Next proposition 2 shows that $a(p)$ is decreasing in $q^N(u)$. This means that firms that use referrals as a search channel invest less effort into formal search activities compared to firms that don't use referrals. Economically, one can say that there is substitution between these two channels. We summarize this prediction in hypothesis H4:

Hypothesis H4: *Firms that use referrals as a search channel invest less into formal search compared to firms that don't use referrals, that is* $a(p)$ *is lower when* $s = 1$ *compared to firms with* $s = 0$.

Finally, so far we have focused on the ex-ante characteristics of hiring. Next we consider the fraction of workers hired by referrals, which is an ex-post economic characteristic. This fraction is given by:

$$\frac{q^N(u)}{a(p)q(\theta) + q^N(u)}$$

Since larger firms invest more effort/money into the formal channel (that is $a(p)$ is increasing in p) the fraction of workers hired by referrals should be decreasing with the firm size. This is our next hypothesis:

Hypothesis H5: *Larger firms are less likely to hire an applicant by referral than smaller firms, that is $q^N(u)/(a(p)q(\theta) + q^N(u))$ is decreasing in p.*

Even though our model differs considerably from the model by Galenianos (2013), both models conclude that low productivity firms exhibit greater prevalence of referrals than high productivity firms (proposition 3.4).

In particular, the model in Galenianos (2013) is based on the perfect substitution mechanism assuming that more productive firms (i.e. larger firms) invest more effort into the formal search channel but at the same time reduce their search intensity through the referral channel. Therefore, the decision of firms to invest more effort into the formal channel doesn't affect the total number of matches or applicants, respectively.

In contrast, our model implies that larger firms invest more formal search effort into the hiring process and on average get a larger number of applications per vacancy per unit time than smaller firms. Indeed, in our model firms also increase the proportion of applications from the formal channel by increasing their search effort $a(p)$. But the difference to Galenianos (2013) is that the absolute number of applicants is allowed to change, because the firms don't necessarily reduce their search effort into the referral channel. Recall that $a(p)q(\theta) + q^N(u)$ is the Poisson arrival rate of applicants, so it is at the same time also the average number of applications per vacancy over a given unit of time. We summarise this result in hypothesis H6:

Hypothesis H6: *Larger firms invest more effort into formal search activities and on average receive a larger number of applications $a(p)q(\theta) + q^N(u)$ per vacancy per unit time than smaller firms.*

Finally, our model predicts that larger firms pay higher wages and that wages are increasing with the skill level of the worker. However, positive returns to schooling and the "firm size effect" in wage regressions are extensively documented in the literature and do not require further testing. Thus, we focus on hypothesis H1-H6 and turn to the description of empirical data in the next section.

3 Data

Our empirical analysis is based on data from the IAB Job Vacancy Survey of the Institute for Employment Research (IAB JVS). The IAB JVS is a representative survey among human resource managers or managing directors in German firms from all sectors of economic activities and from all company size classes. One of the main objectives of the survey is to explore the recruiting processes. In each wave of the survey, a representative sample of companies and administrations with at least one employee subject to social security contributions is taken from the employment statistics of the Federal Employment Agency. The survey is stratified disproportionately, structured into 28 economic activities and seven company size classes, and is drawn separately for Eastern and Western Germany.

The gross sample comprises between 75,000 and 85,000 addresses and the response rate is about 20 percent (for more information see Brenzel et al., 2016; Kettner et al., 2011). Generally, the sample for the different waves is newly drawn each year. This implies that most firms are observed only once during the observation period and only a small part of firms appears more than once. Since it is not possible to explicitly identify these firms, our data has the characteristics of a cross-sectional sample, observed in different years.

To get information about recruiting processes, a part of the questionnaire focusses on the last case of hiring in the previous twelve months. The firms report in detail the last case of a successful and of an unsuccessful recruitment.[3] This includes information about search strategies used by the firm. We classify all strategies either into the formal or into the informal search channel, thus employee's referrals.

In case of successful recruitment, there is also information available on the one strategy that finally turned out to be successful. Mouw (2003) refers to the works of Montgomery (1992) and discusses the problem of 'multiple methods of job search' when considering the process of search from the perspective of workers. In particular, he points out that comparing ex-post frequencies of finding a job formally or by referral is 'a misleading way to determine the effectiveness of job search methods if workers use multiple methods of job search' (Mouw, 2003: p. 870) because workers' ex-ante search effort attached to these channels can be different. The same problem may arise in the context of firms' search and therefore we follow the proposal of Krug/Rebien (2012) and use formal search effort of firms as explanatory variable.

The formal channel includes 1) placing ads in newspapers or magazines, 2) posting the vacancy in the internet, 3) posting a vacancy on the firm's own website, 4) contacting the federal employment agency, 5) contacting a private employment agency, and 6) considering the pool of unsolicited applications.[4].

From this information we constructed an ordinal proxy variable for the formal search intensity of firms a_i, which takes discrete values in the range $[0..6]$. For example, $a_i = j > 0$ implies that firm i used j formal channels to fill the position. Figure 3 shows the histogram

[3] The logic of the questionnaire renders it possible to get detailed information on recruitment processes. One potential drawback of this methodology is that it is not possible to derive information on the probability how successful firms and their recruitment strategies are. However, this is not of importance for our paper.

[4] We assigned the most convenient search strategies to the formal channel. However, the survey distinguishes a few further search strategies, e.g., internal job postings, selection of apprentices, leased workers or interns. We excluded these search strategies from our analysis because these strategies are considered by the survey only for certain years and these strategies cannot be clearly assigned to the formal or the informal channel.

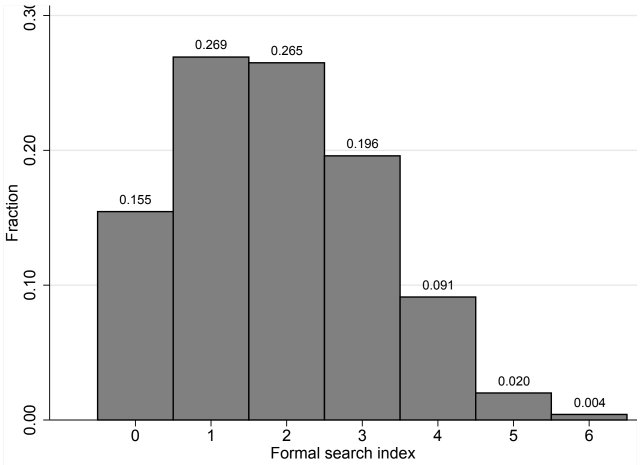

Figure 3: Distribution of the number of chosen formal search channels by firms (fractions)

Note:N=42,112

Source: IAB Job Vacancy Survey 2012-2016.Own computations.

for this variable. We can see that most of the firms use one, two, or three search channels, followed by firms that use no formal search channel. Note that $a_i = 0$ implies that the firm was exclusively relying on referrals in the search process. The histogram reveals that very few firms use four, five, or six search channels.

If the firm used at least one of the formal strategies to find job candidates we set $y_i^F = 1$, otherwise $y_i^F = 0$. This is a binary indicator variable for the formal job search. We use a similar indicator $s_i = 1$ if the firm was using referrals to fill the position, otherwise $s_i = 0$. Note that $a_i = 0$ automatically implies that $s_i = 1$ but not vice versa. Finally, $y_i^S = 1$ if the worker was recruited by referral and $y_i^S = 0$ if it was the formal channel. This ex-post information is only available for successful recruitment cases.

The data for successful recruitment gives information on the characteristics of the vacancy to be filled, such as whether the position requires additional skills, e.g. leadership abilities.[5] Additionally, information about the previous employment status of (successfully) hired workers is available. All in all, about 9,000 companies answer this part of the questionnaire in each year, from which around 1,000 report unsuccessful recruiting attempts. For our main analysis, we use data from the years 2012 to 2016, because information about abortions of recruitment processes is only available for this observation period.

Though due to the extensive use of control variables we loose a number of observations, our restricted sample remains representative. We checked this by comparing the frequency statistics of the stratification variables for each constructed data set. Figure 4 illustrates the number of observed recruitment cases by the two search channels and successful or unsuccessful recruiting. This also illustrates the logic of our analysis; at first, firms decide to use referrals, to search via the formal channel or to use both channels simultaneously. Then the following recruiting process is either unsuccessful, thus the firm has to abort the recruitment activity without a hiring, or it is successful. In the latter case we can observe by which of the two channels the worker was hired.

[5] This data is not available for unsuccessful recruitment.

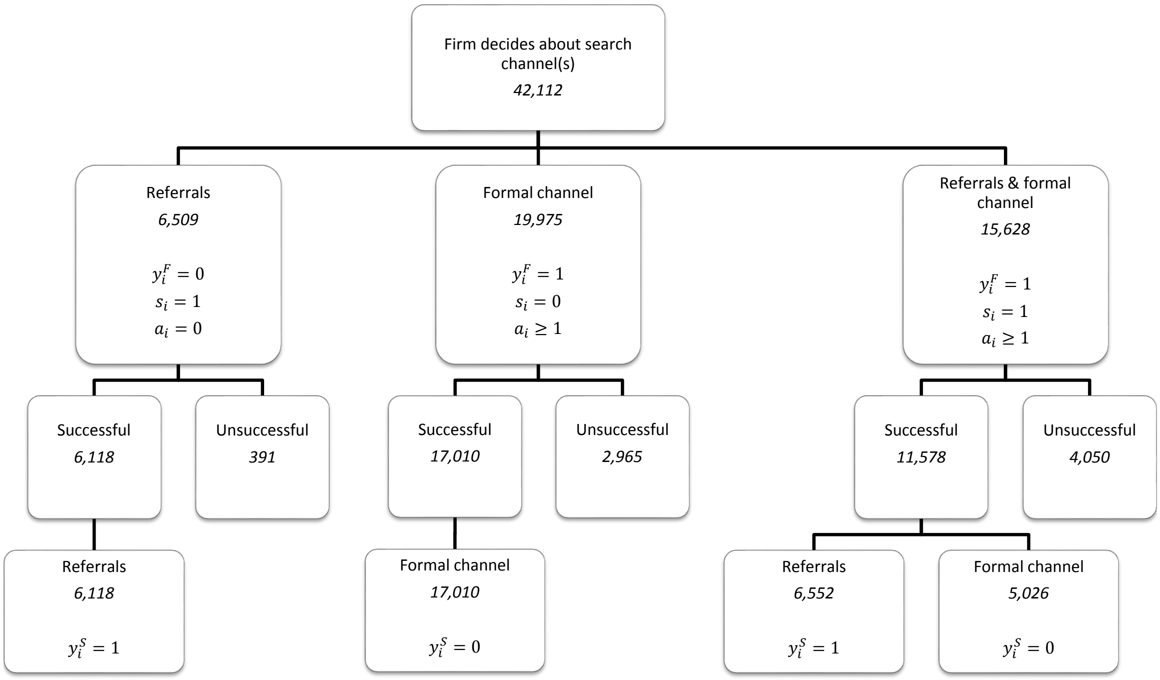

Figure 4: Number of cases of successful and unsuccessful recruitment reported by firms

Note: Number of observation is not equal to number of firms since some firms report one successful and one unsuccessful case of recruitment. Number of firms in the sample is 36,704.

Source: IAB Job Vacancy Survey 2012-2016. Own computations.

Table 1 shows descriptive statistics for the survey variables that are most important for the hypotheses H1-H6 from the theoretical part. The table consists of six panels; each of these panels refers to one of the hypotheses (compare with the headlines); the fifth panel consists of two parts, (i) and (ii), that both refer to hypothesis H5.

The first panel presents the average formal search index a_i by firm size (2nd column) and the relative frequencies of firms that search formally y_i^F (3rd column). The 4th column contains the absolute number of observed firms. These averages, frequencies and numbers are split by four firm size classes, i.e. "one to 9 employees", "10 to 49 employees", "50 to 249 employees", and "250 and more employees". We find that both the averages of the formal search index and the relative frequency of firms that use formal ways increase with an increasing firm size. This finding would be in line with hypothesis H1.

The second panel, that refers to hypothesis H2, shows the average formal search index a_i (2nd column) and the relative frequencies of firms that use formal search activities y_i^F (3rd column) by the required skill levels. Column 4 contains again the observation numbers. The required skill levels include the following three categories: "no qualification necessary", "vocational training", and "university degree". Both the average formal search index and the relative frequency of firms that search formally increase with a higher required skill level. This would be in line with hypothesis H2.

The third panel, that refers to hypothesis H3, presents averages of the formal search index by firm size. The difference to the upper panel is that the sample is restricted to firms that don't use referrals; thus all firms in the sample search exclusively through the formal channel, i.e. $s_i = 0$ and $a_i > 0$. We find again that this search index increases on average with an increasing firm size. This finding corroborates hypothesis H3.

The fourth panel, that refers to hypothesis H4, presents the average formal search index of firms that either use referrals $s_i = 1$ or don't use referrals $s_i = 0$, again split by the four firm size classes. We find that the average intensities of firms that use referrals are smaller compared to firms that don't use referrals; this is in line with hypothesis H4.

Part (i) of the fifth panel, that refers to hypotheses H5, presents the relative frequencies of referral $(y_i^S = 1)$ and formal placements $(y_i^S = 0)$ split by the four firm size classes. We see that these frequencies become smaller with larger firm size.

Naturally, in a sample with successful recruitment that contains also firms that use either only referrals or formal ways the results in the fifth panel are predetermined for these firms. We consider this in part (ii) of the fifth panel that shows the same relative frequencies like part (i) but the underlying sample is restricted to firms that used both ways, referrals and formal channels. Note that this sample is intuitively closer to our theoretical model in which all firms always use both search channels. Our finding from above remains qualitatively the same; again, the relative frequencies of firms that hired their workers by referrals decreases with an increasing firm size. This is in line with hypothesis H5.

The sixth panel provides first evidence regarding hypothesis H6. In our data we have information about the number of applications received by firms. However, a direct comparison

Table 1: Descriptives of the most important variables for Hypotheses H1–H6.

Hypothesis H1: Formal search and firm size

	Use of formal channels y_i^F	Formal search index a_i	
	Rel. freq.	Mean	N
Number of employees(4 firm size classes)			
$1 \leq ee < 10$	0.71	1.35	5,507
$10 \leq ee < 50$	0.82	1.72	21420
$50 \leq ee < 250$	0.91	2.17	10,714
$250 \leq ee$	0.96	2.56	4,471
Total	0.85	1.88	42,112

Hypothesis H2: Formal search and skill requirements

	Use of formal channels y_i^F	Formal search index a_i	
	Rel. freq.	Mean	N
Skill requirements			
w/o qualification	0.76	1.53	5,528
Vocational training	0.85	1.85	29,059
University degree	0.90	2.23	7,525
Total	0.85	1.88	42,112

Hypothesis H3: Formal search and firm size, restricted to firms that use only the formal channel and don't use referrals

	Formal search index $a_i > 0$	
	Mean	N
Number of employees(4 firm size classes)		
$1 \leq ee < 10$	1.84	1,961
$10 \leq ee < 50$	2.02	9,425
$50 \leq ee < 250$	2.30	5,761
$250 \leq ee$	2.57	2,828
Total	2.16	19,975

Hypothesis H4: Formal search intensity by firms that either use referrals or not

	Use of referrals s_i			
	no	yes	all	
	Mean of formal search index a_i			N
Number of employees (4 firm size classes)				
$1 \leq ee < 10$	1.84	1.08	1.35	5,507
$10 \leq ee < 50$	2.02	1.49	1.72	21,420
$50 \leq ee < 250$	2.30	2.02	2.17	10,714
$250 \leq ee$	2.57	2.55	2.56	4,471
Total	2.16	1.62	1.88	42,112

Hypothesis H5: Placement with referral by firm size, only for successful recruitment cases

(i) firms that used referrals, formal ways or both referrals and formal ways

	Placement by referral y_i^S	
	Rel. freq.	N
Number of employees (4 firm size classes)		
$1 \leq ee < 10$	0.54	4,166
$10 \leq ee < 50$	0.41	17,678
$50 \leq ee < 250$	0.27	9,074
$250 \leq ee$	0.17	3,788
Total	0.37	34,706

(ii) firms that used both referrals and formal ways

	Placement by referral y_i^S	
	Rel. freq.	N
Number of employees (4 firm size classes)		
$1 \leq ee < 10$	0.64	1,220
$10 \leq ee < 50$	0.61	6,115
$50 \leq ee < 250$	0.51	3,105
$250 \leq ee$	0.42	1,138
Total	0.57	11,578

Hypothesis H6: Numbers of applicants per vacancy and search duration by firm size

	Average number of applicants per vacancy and search duration	N
Number of employees (4 firm size classes)		
$1 \leq ee < 10$	0.25	3,238
$10 \leq ee < 50$	0.35	14,042
$50 \leq ee < 250$	0.50	7,606
$250 \leq ee$	0.71	3,383
Total	0.42	28,269

Source: IAB Job Vacancy Survey 2012-2016. Own computations.

of the number of applications across firms can be misleading because firms may choose different time spells between the moment when the position is posted and the application deadline. Thus, we control for these differences by dividing the number of applications by the search duration to make sure that we compare the number of applications over the same time period for all firms. Search duration is measured in days and it is defined as the period from the start of the firm's search until cancelation of the firm's search or a firm's positive recruitment decision; in our sample, the firms searched in average for 82.8 days (with a standard deviation of 105.9). Therefore, the sixth panel reports average numbers of applications per day by the four firm size groups. We can see that the average number of applications per day increases with the size of the firm. This finding is in line with hypothesis H6.

In our empirical analysis we carefully evaluate these findings by different multivariate regression models that include a row of further controls that allow us to consider temporal shocks and cross sectional heterogeneity. For the analyses based on all recruitment processes with and without successful recruitment, these controls comprise the share of employees without any qualification, the share of employees with vocational training and the share of employees with a university degree. In the survey, this data is available for 34,362 of 42,112 observations. We imputed missing values for the remaining 7,750 observations with sector and firm size averages of the employment shares.[6] The upper part of table 2 presents means and standard deviations of these variables. With an average of 73 per cent, the share of employees with vocational training in a firm is much larger than the share of employees without qualification or employees with a university degree in the same firm. According to the standard deviations there is huge variation of these shares across the observed firms.

For the analyses based on recruitment processes that were successful, the controls additionally comprise information whether there are further skill requirements like leadership ability, adequate experience, skills from a training program outside the standard vocational training, social skills, and foreign languages. We compare relative frequencies and standard deviations of these variables in the middle part of table 2. Here we see, that social skills (35 per cent of all successful recruitment cases) or experience (34 per cent of all successful recruitment cases) are rather often asked for, whereas leadership abilities and foreign languages are otherwise rarely required (9 per cent and 8 per cent, resp., of all successful recruitment cases). Again the standard deviations are relatively large and indicate large variation of the further skill requirements across all observations of successful recruitment cases.

For our analysis of recruitment channels that were finally successful we use also information on the former employment status of the recruited workers; this status is either "out of

[6] In doing so, we computed the totals of the employees belonging to a certain skill level (i.e. without any qualification, vocational training, or university degree) within each of 23 economic sectors and one of seven firms size classes ("$1 \leq ee < 10$", "$10 \leq ee < 20$", "$20 \leq ee < 50$", "$50 \leq ee < 200$", "$200 \leq ee < 500$", "$500 \leq ee < 1000$", "$1000 \leq ee$"). Then we divided each of these totals by the total of all employees within the same economic sector and the same firm size class. Therefore, we get an average share of employees with certain skill level by economic sectors and firm size classes that we use as proxy for the employee share in a firm without information about the employment share and that belongs to the adequate economic sector and size class.

Table 2: Descriptive statistics of further control variables.

	Mean	Stand. dev.
Employee shares by skill level		
Share of unskilled workers	0.10	0.18
Share of skilled workers with vocational training	0.73	0.25
Share of skilled workers with university degree	0.17	0.22
N	42,112	
Only for successful recruitment cases	Rel. frequency	Stand. dev.
Additional skill requirements (multiple answers allowed)		
Leadership ability	0.09	0.29
Experience	0.34	0.47
Skills acquired from a training program outside the standard vocational training	0.20	0.40
Foreign languages	0.08	0.28
Social skills	0.35	0.48
Former employment status of recruited workers		
Employed	0.66	0.47
Unemployed	0.26	0.44
Out of labor force	0.08	0.27
N	34,706	

Source: IAB Job Vacancy Survey 2012-2016. Own computations.

labor force", "unemployed", or "employed" and it is coded in 3 dummy variables. The lower part of table 2 reports relative frequencies and their standard deviations and we can see that most of the recruited workers were "employed" before, followed by workers that were "unemployed", and far less workers were "out of labor force". Given that in our theoretical model there is no on-the-job search, we pay special attention to workers hired from unemployment and report our empirical results separately for the full sample and for the restricted sample of previously unemployed applicants.

Finally, all our specifications contain dummy variables for the German federal states, for the 23 economic sectors, for the observation years, and for the distinction of firms that report either a succesful or an unsuccesful case of recruitment versus firms that report both.

4 Empirical strategy and results

For the exploration of hypotheses H1 and H2 we use a simple logistic model:

$$Prob(y_i^F = 1|\mathbf{x_i}) = \frac{\exp(b_0 + \mathbf{b_1 x_i})}{1 + \exp(b_0 + \mathbf{b_1 x_i})} = \frac{1}{1 + \exp[-(b_0 + \mathbf{b_1 x_i})]} \tag{10}$$

The term $Prob(y_i^F = 1|\mathbf{x_i})$ denotes firm's i probability of using the formal search channel (y_i^F equals 1 in case of using the formal search channel and 0 otherwise). At this stage, firm's i size and the required skill level are the explanatory variables we are interested in.

Regarding the firm size, we defined four groups (less than 10 employees, 10 to less than 50 employees, 50 to less than 250 employees, and 250 and more employees) and assigned every firm to one of these groups. This corresponds to three size dummy variables (the group of firms with less than 10 employees is the reference group and, therefore, excluded). Regarding the skill level, we can distinguish the jobs that don't require any formal qualification from jobs that require vocational training and jobs that require a university degree.

This gives us two skill level dummy variables with "no formal qualification requirement" as reference category.

All these dummy variables are stacked with a number of further covariates in the column vector $\mathbf{x_i} = (x_{i1} x_{i2} \cdots x_{ik})'$. The corresponding coefficients are stacked in row vector $\mathbf{b_1} = (\beta_{11}\beta_{12} \cdots \beta_{1k})$.

In all our estimations we include year dummies, dummies for the federal states where the firms are located, industrial sectors, and a dummy that indicates firms reporting both the last case of a successful and an unsuccessful recruitment. We also add stepwise firm, vacancy, and worker specific properties; further details about the covariates follow along the description of the result tables. We report cluster robust standard errors by federal states and we generally report odds ratios[7].

The analysis is based on observational years from 2012 - 2016 because in these years we have information on abortions of recruitment processes. This gives us the opportunity to analyse the probability of formal search, regardless whether the recruitment process ended up with a new hire or not.

Table 3 presents the estimates.

Results in column 1 stem from a specification where the right hand side consists only of 3 firm size class dummies (with the smallest firm size class of at least one employee up to 9 employees) and the mentioned controls.

Column 2 presents results of a specification that contains information about the skill level requirement of the job; i.e., there is a dummy in the case that the job requires vocational training and a dummy in the case that the job requires a university degree. The reference category is equivalent to cases the job requires no qualification.

Results in column 3 are based on a specification with both firm size class dummies and skill requirement dummies.

Column 4 presents the results of the regression estimates based on the specification before and complemented by information about the employment structure in terms of the share of employed who completed vocational training and the share of employed university graduates (reference category is the share of employees without a qualification; this share would sum up with the other shares to 1 and must be excluded from the regression equation).

In columns 5 and 6 we restrict the sample and exclude cases of unsuccessful search. The specification in column (5) is the same as in column (4) and the specification in column (6) considers further control variables that refer to additional skill requirements, more precisely leadership ability, experience, skills from training outside formal qualification, foreign languages, and social skills.

[7] Given that $P_i \equiv Prob(y_i = 1)$, the odds are $\frac{P_i}{(1-P_i)} = \exp(b_0)\exp(\beta_{11}x_{i1}) \cdot ... \cdot \exp(\beta_{1k}x_{ik})$.Thus, for a certain covariate (x_{ij} with $1 \leq j \leq k$) that is increased by 1, the change in the log-odds ratio ($\ln \frac{P_i}{(1-P_i)}$) is equal to (β_{1j}). In all result tables we report $\exp(\beta_{1j})$; values below 1 (thus, $\beta_{1j} < 0$) indicate a negative effect on the odds and values larger than 1 indicate a positive effect (thus, $\beta_{1j} > 0$).

Table 3: Empirical results: Probability of using the formal channel in recruiting processes as dependent variable, $Prob(y_i^F = 1)$

	All observations				Only successful recruitment cases	
	(1)	(2)	(3)	(4)	(5)	(6)
	logit	logit	logit	logit	logit	logit
Number of employees (4 firm size classes, reference: 1 ≤ ee < 10)						
10 ≤ ee < 50	1.938***		1.888***	1.898***	2.169***	2.177***
	(0.073)		(0.074)	(0.073)	(0.097)	(0.096)
50 ≤ ee < 250	4.357***		4.172***	4.212***	4.932***	4.940***
	(0.303)		(0.301)	(0.308)	(0.378)	(0.383)
250 ≤ ee	9.680***		8.709***	8.868***	10.503***	10.368***
	(0.799)		(0.673)	(0.688)	(0.920)	(0.897)
Skill requirements, reference: w/o qualification						
Vocational training		1.839***	1.772***	1.717***	1.658***	1.613***
		(0.083)	(0.082)	(0.080)	(0.076)	(0.076)
University degree		2.935***	2.220***	1.976***	1.847***	1.814***
		(0.184)	(0.125)	(0.104)	(0.097)	(0.096)
Further control variables						
Employee shares by skill level				x	x	x
Additional skill requirements						x
Observations	43,378	42,113	42,113	42,112	34,706	34,706
Pseudo R-squared	0.101	0.0673	0.107	0.108	0.101	0.104

Federal states cluster robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: Coefficients are reported as odds ratios, where a zero effect is 1. All specifications include year dummies, dummies for the federal states where the firms are located, industrial sectors, and a dummy that indicates firms reporting both the last case of a successful and an unsuccessful recruitment case. Firms size class based on all employees, regardless whether employees are subject to social security contributions or not. Firms are considered that used exclusively referrals, exclusively formal ways, or both referrals and formal ways as search channels ($s_i \geq 0, 0 \leq a_i \leq 6$). Employee shares by skill level comprise three groups: unskilled workers, skilled workers with vocational training, skilled workers with university degree. Additional skill requirements are a set of dummy variables that denote whether the vacancy requires leadership ability, experience, further skills from training outside formal qualification, foreign languages, and/or social skills. Detailed results on the further control variables are presented in the Appendix VI, table 16.
Source: IAB Job Vacancy Survey 2012-2016. Own computations.

From table 3 we conclude that the probability of using the formal channel by firms is higher in larger firms and it is also higher for job positions that require higher skill levels, since the coefficient for the requirement of a university degree is higher than for the requirement of vocational training and the latter is higher than for no qualification requirements. These results are robust throughout all presented specifications.[8]

We also computed average predicted probabilities for our parameters of interest from our preferred specification in column 4 of table 3, see table 4. The probability that firms use formal ways as search strategy is 72 per cent in the case all firms would employ between 1 and 10 workers. The probability is 83 per cent in the case all firms would employ between 10 and 50 workers; 91 per cent in the case all firms would employ between 50 and 250 workers; and 95 per cent in case all firms would employ 250 or more workers. Columns 4 and 5 show the estimates for the 95 per cent confidence bands for the probabilities and we can conclude that these probabilities differ significantly. This is further evidence in favour of hypothesis H1.

Table 4: Average predicted probabilities of using formal ways as search strategy, given different firm size classes and skill requirements.

Variable	Pred. probab.	Std. Err.	[95% Conf.	Interval]
Number of employees (4 firm size classes)				
$1 \leq ee < 10$	0.724	0.005	0.713	0.735
$10 \leq ee < 50$	0.827	0.002	0.822	0.831
$50 \leq ee < 250$	0.911	0.004	0.902	0.919
$250 \leq ee$	0.955	0.003	0.948	0.961
Skill requirements				
w/o qualification	0.781	0.006	0.770	0.793
Vocational training	0.854	0.001	0.851	0.856
University degree	0.869	0.004	0.861	0.877

Note: Average predicted probabilities of using formal channel, standard errors and 95 per cent confidence intervals based on the specification estimates in column 4 in table 3.
Source: IAB Job Vacancy Survey 2012-2016. Own computations.

According to the lower part of table 4, the probability that firms use formal ways as a search strategy is 78 per cent in the case all job openings would require only workers without qualification. The probability is 85 per cent in the case all firms job openings would require only workers with vocational training; 87 per cent in the case all firms job openings would require only workers with a university degree. According to the results for the 95 per cent confidence bands, these probabilities differ significantly. This is further evidence in favour of Hypothesis H2.

However, hypotheses H1 and H2 refer to the formal search intensity of firms rather than the probability of using the formal channel. Though we are not able to construct the ideal continuous measure, our data allows us to compute an ordinal indicator that is equal to the sum of the search strategies that firms decided to use and that are assigned to the formal channel. This indicator variable was defined above and is denoted by a_i. In our sample firms used between 0 and 6 of these strategies[9], with a median of 2 chosen search

[8] Table 16 in appendix VI contains the coefficients on further control variables. For example, we can see that firms are less likely to use the formal channel when they are looking for workers with leadership abilities and experience.

[9] The maximum must be 6, because we assign 6 strategies (placing ads in newspapers or magazines, posting

strategies. So we computed an ordinal indicator for the formal search intensity, based on the assumption that the formal search intensity is higher the more formal strategies are used. In what follows, we analyse the influence of firm size and skill level requirements on the search intensity indicator with an ordered logit model:

$$Prob(a_i = j) = Prob(\kappa_{j-1} < b_0 + \mathbf{b_1 x_i} + u_i \leq \kappa_j) \tag{11}$$

The probability $Prob(a_i = j)$ of the outcome $j = 0, ..., 6$ corresponds to the probability that the estimated linear function, plus the error term[10], u_i, is within the range of the cutpoints $\kappa_0, \kappa_1, ..., \kappa_5$. These are simultaneously estimated with the coefficients $b_0, \beta_{11}, \beta_{12}, \cdots \beta_{1k}$. In our analysis κ_{-1} goes to $-\infty$ and κ_6 to ∞. Table 5 reports the estimates, based on the sample of firms that use at least referrals as search channel ($s_i = 1$). This is close to hypothesis H1 in our theoretical model in which the usage of referrals is given in any case because this is assumed to be a costless channel. The different models in columns (1) to (6) are specified analogous to the previous table 3.

Table 5: Empirical results: Search intensity through the formal channel, a_i, as dependent variable.

	All observations				Only successful recruitment cases	
	(1)	(2)	(3)	(4)	(5)	(6)
	ord. logit	ord. logit	ord. logit	ord. logit	ord. logit	ord. logit
Number of employees (4 firm size classes, reference: 1 ≤ ee < 10)						
10 ≤ ee < 50	1.775***		1.728***	1.737***	2.029***	2.041***
	(0.054)		(0.053)	(0.052)	(0.066)	(0.067)
50 ≤ ee < 250	3.424***		3.289***	3.304***	4.038***	4.051***
	(0.144)		(0.136)	(0.139)	(0.204)	(0.208)
250 ≤ ee	6.252***		5.688***	5.742***	7.385***	7.326***
	(0.375)		(0.325)	(0.345)	(0.479)	(0.507)
Skill requirements, reference: w/o qualification						
Vocational training		1.593***	1.561***	1.554***	1.487***	1.415***
		(0.065)	(0.072)	(0.072)	(0.066)	(0.062)
University degree		2.470***	1.975***	1.868***	1.721***	1.611***
		(0.131)	(0.111)	(0.109)	(0.115)	(0.111)
Further control variables						
Employee shares by skill level				x	x	x
Additional skill requirements						x
Observations	22,828	22,137	22,137	22,137	17,696	17,696
Pseudo R-squared	0.0604	0.0433	0.0625	0.0626	0.0573	0.0594

Federal states cluster robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: Coefficients are reported as odds ratios, where the null effect is 1. All specifications include year dummies, dummies for the federal states where the firms are located, industrial sectors, and a dummy that indicates firms reporting both the last case of a successful and an unsuccessful recruitment case. Firms size class based on all employees, regardless whether employees are subject to social security contributions or not. Firms are considered that used exclusively referrals or both referrals and formal ways as search channels ($s_i = 1, 0 \leq a_i \leq 6$). Employee shares by skill level comprise three groups: unskilled workers, skilled workers with vocational training, skilled workers with university degree. Additional skill requirements are a set of dummy variables that denote whether the vacancy requires leadership ability, experience, further skills from training outside formal qualification, foreign languages, and/or social skills. Detailed results on the further control variables are presented in the Appendix VI, table 17.
Estimated cutpoints for specification in column (4):
$\kappa_0 = 1.415615$, $\kappa_1 = 2.483963$, $\kappa_2 = 3.568742$, $\kappa_3 = 4.740601$, $\kappa_4 = 6.289588$, $\kappa_5 = 7.893848$
Source: IAB Job Vacancy Survey 2012-2016. Own computations.

We can see that in all specifications the formal search indicator increases with a larger firm

the vacancy in the internet, posting a vacancy on the firm's own website, contacting the federal employment agency, contacting a private employment agency, and considering the pool of unsolicited applications) to the formal channel in the survey throughout the observation period. The arithmetic mean is 1.68 with a standard deviation of 1.17. This shows that the index values vary sufficiently over the firms.

[10] The error term is assumed to be logistically distributed.

size and with a higher qualification requirement of the position. According to our results, the search intensity is lower for job positions without a qualification requirement, it is somewhat higher with vocational training, and still higher for jobs that require a university degree. Thus, hypotheses H1 and H2 cannot be rejected.

However, the survey also includes firms that reported that they used only the formal channel for their worker search, that is $s_i = 0$. According to hypothesis H3 derived from our theoretical model, formal search intensity should then depend on firm size in the same direction. To validate this, we reestimated the last specifications based on a sample that includes only firms that searched exclusively via the formal channel. Note that a_i must be larger than 0 now, thus only five cutpoints ($\kappa_1, \kappa_2, ..., \kappa_5$) will be estimated. Table 6 contains the results. Again, the formal search intensity, a_i, increases with firm size. Thus, hypothesis H3 cannot be rejected.

Table 6: Empirical results: Search intensity through the formal channel as dependent variable, a_i, restricted sample.

	All observations				Only successful recruitment cases	
	(1)	(2)	(3)	(4)	(5)	(6)
	ord. logit	ord. logit	ord. logit	ord. logit	ord. logit	ord. logit
Number of employees (4 firm size classes, reference: 1 ≤ ee < 10)						
10 ≤ ee < 50	1.403***		1.348***	1.349***	1.404***	1.413***
	(0.057)		(0.051)	(0.052)	(0.065)	(0.067)
50 ≤ ee < 250	2.362***		2.200***	2.202***	2.274***	2.271***
	(0.111)		(0.109)	(0.113)	(0.128)	(0.127)
250 ≤ ee	3.647***		3.135***	3.136***	3.154***	3.121***
	(0.290)		(0.240)	(0.250)	(0.262)	(0.257)
Skill requirements, reference: w/o qualification						
Vocational training		1.902***	1.871***	1.864***	1.868***	1.694***
		(0.142)	(0.133)	(0.130)	(0.130)	(0.119)
University degree		3.134***	2.601***	2.581***	2.583***	2.232***
		(0.261)	(0.184)	(0.217)	(0.219)	(0.192)
Further control variables						
Employee shares by skill level				x	x	x
Additional skill requirements						x
Observations	20,550	19,976	19,976	19,975	17,010	17,010
Pseudo R-squared	0.0304	0.0241	0.0362	0.0362	0.0357	0.0384

Federal states cluster robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: Coefficients are reported as odds ratios, where the null effect is 1. All specifications include year dummies, dummies for the federal states where the firms are located, industrial sectors, and a dummy that indicates firms reporting both the last case of a successful and an unsuccessful recruitment case. Firms size class based on all employees, regardless whether employees are subject to social security contributions or not. Firms are considered that used exclusively formal ways as search channels ($s_i = 0, 1 \leq a_i \leq 6$). Employee shares by skill level comprise three groups: unskilled workers, skilled workers with vocational training, skilled workers with university degree. Additional skill requirements are a set of dummy variables that denote whether the vacancy requires leadership ability, experience, further skills from training outside formal qualification, foreign languages, and/or social skills. Detailed results on the further control variables are presented in the Appendix VI, table 18.
Estimated cutpoints for specification in column (4):
$\kappa_1 = 1.114071, \kappa_2 = 2.551012, \kappa_3 = 4.075527, \kappa_4 = 6.015036, \kappa_5 = 8.273729$
Source: IAB Job Vacancy Survey 2012-2016. Own computations.

An important underlying economic assumption of our theoretical model is that the search by referrals and formal search are regarded as substitutes. To test for this we used the same ordered logit specification as before but added referral dummy, s_i, as an additional explanatory variable. Our results are presented in table 7. The first column presents the results of a specification that includes only the dummy variable for the usage of referrals. Afterwards we gradually add the set of further control variables. The results in columns 2 to 7 are based on specifications that are similar to columns 1 to 6 in the previous result tables.

Table 7: Search intensity in formal ways, a_i, and the usage of referrals.

	All observations					Only successful recruitment cases	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	ord. logit	ord. logit	ord. logit	ord. logit	ord. logit	ord. logit	ord. logit
Usage of referrals	0.413***	0.449***	0.431***	0.462***	0.462***	0.388***	0.385***
	(0.015)	(0.017)	(0.017)	(0.018)	(0.018)	(0.014)	(0.014)
Further control variables							
Number of employees (4 firm size classes)		x		x	x	x	x
Skill requirements			x	x	x	x	x
Employee shares by skill level					x	x	x
Additional skill requirements							x
Observations	43,378	43,378	42,113	42,113	42,112	34,706	34,706
Pseudo R-squared	0.0426	0.0604	0.0481	0.0632	0.0632	0.0679	0.0698

Federal states cluster robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: Coefficients are reported as odds ratios, where the null effect is 1. All specifications include year dummies, dummies for the federal states where the firms are located, industrial sectors, and a dummy that indicates firms reporting both the last case of a successful and an unsuccessful recruitment case. Firms size class based on all employees, regardless whether employees are subject to social security contributions or not. Firms are considered that used both or either exclusively formal ways or referrals as search channels ($s_i \geq 0, 0 \leq a_i \leq 6$). The number of employees comprises four firm size classes: "one to 9 employees" (reference group), "10 to 49 employees", "50 to 249 employees", and "250 and more employees". The employee shares by skill level comprise three groups: unskilled workers, skilled workers with vocational training, skilled workers with university degree. The additional skill requirements are a set of dummy variables that denote whether the vacancy requires leadership ability, experience, further skills from training outside formal qualification, foreign languages, and/or social skills. Detailed results on the further control variables are presented in the Appendix VI, table 19.
Estimated cutpoints for specification in column (5):
$\kappa_1 = .0026124$, $\kappa_2 = 1.614542$, $\kappa_3 = 2.873646$, $\kappa_4 = 4.226648$, $\kappa_5 = 5.932604$, $\kappa_6 = 7.724602$
Source: IAB Job Vacancy Survey 2012-2016. Own computations.

We can see from this table that the usage of referrals is negatively correlated with the search intensity. Thus, Hypothesis H4 cannot be rejected and this corroborates the assumption that formal search and referrals are regarded as substitutes in firms' worker search, even though the search by referral is relatively cheap or costless.

We now test hypothesis H5 and estimate the probability of referral hiring with a logit model. Our results refer to the restricted sample of firms that decided to search by using both the formal channel and referrals simultaneously. This restriction is necessary because for firms that use exclusively only one of these two channels, the successful channel would be predetermined. Note that in these regression specifications we can additionally control for the former employment status of the worker (employed or unemployed, reference is the group of workers that come from out of labour force).

Table 8 presents our results.

We clearly see that larger firms are less likely to hire a worker by referral (column 1). The question now is whether this effect is explained by higher formal search intensity a_i (as predicted by our theoretical model) or not. From column 2 of this table we can see that

Table 8: Empirical results: Probability to recruit with referrals as dependent variable (y_i^S)

	(1) logit	(2) logit	(3) logit	(4) logit	(5) logit	(6) logit	(7) logit
Number of employees (4 firm size classes, reference: 1 ≤ ee < 10)							
10 ≤ ee < 50	0.826***		0.873**	0.878*	0.869**	0.871**	0.872*
	(0.051)		(0.059)	(0.064)	(0.059)	(0.060)	(0.063)
50 ≤ ee < 250	0.552***		0.646***	0.651***	0.645***	0.646***	0.648***
	(0.042)		(0.057)	(0.059)	(0.058)	(0.057)	(0.058)
250 ≤ ee	0.372***		0.490***	0.500***	0.491***	0.494***	0.497***
	(0.040)		(0.058)	(0.062)	(0.059)	(0.057)	(0.062)
Formal search index		0.658***	0.677***	0.681***	0.678***	0.678***	0.680***
		(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
Former employment status, reference: out of labor force							
unemployed	0.608***	0.634***	0.627***	0.610***	0.623***	0.623***	0.607***
	(0.049)	(0.051)	(0.050)	(0.053)	(0.049)	(0.049)	(0.052)
employed	0.894**	0.915	0.943	0.950	0.944	0.943	0.946
	(0.050)	(0.050)	(0.051)	(0.057)	(0.051)	(0.051)	(0.056)
Further control variables							
Skill requirements				x			x
Employee shares by skill level					x		x
Additional skill requirements						x	x
Observations	11,883	11,883	11,883	11,578	11,883	11,883	11,578
Pseudo R-squared	0.0261	0.0535	0.0602	0.0607	0.0609	0.0618	0.0624

Federal states cluster robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: Coefficients are reported as odds ratios, where the null effect is 1. All specifications include year dummies, dummies for the federal states where the firms are located, industrial sectors, and a dummy that indicates firms reporting both the last case of a successful and an unsuccessful recruitment case. Firms size class based on all employees, regardless whether employees are subject to social security contributions or not. Firms are considered that used both referrals and formal ways as search channels ($s_i = 1, 1 \leq a_i \leq 6$). The skill requirements comprise three levels: w/o qualififcation (reference group), vocational training, or university degree.The employee shares by skill level comprise three groups: unskilled workers (reference group), skilled workers with vocational training, skilled workers with university degree. The additional skill requirements are a set of dummy variables that denote whether the vacancy requires leadership ability, experience, further skills from training outside formal qualification, foreign languages, and/or social skills. Detailed results on the further control variables are presented in the Appendix VI, table 20.
Source: IAB Job Vacancy Survey 2012-2016. Own computations.

the formal search intensity a_i has a significant negative effect on the probability of hiring a worker by referral. Moreover, the coefficients on the three firm size variables are higher in column 3 and closer to 1. Given that we report the model in terms of odds-ratios this means that the negative effect of the firm size on the probability of referral hiring is largely mitigated and is closer to zero once we control for the higher formal search intensity of larger firms. Therefore, the mechanism described in our model is supported by empirical data even though the firm size coefficients remain significant.[11]

We computed average predicted probabilities for referrals as successful recruitment strategy for the four firm size classes based on our preferred specification in column 7 of table 8, see table 9. The probability that firms successfully use referrals as search strategy is 62 per cent in the case all firms would employ between 1 and less than 10 workers. The probability is 59 per cent in the case all firms would employ between 10 and 50 workers; 53 per cent in the case all firms would employ between 50 and 250 workers; and 46 per cent in case all firms would employ 250 or more workers. Columns 4 and 5 show the estimates for the 95 per cent confidence bands for the probabilities and we can conclude that these probabilities differ significantly. Thus, according to these results hypothesis H5 cannot be rejected.

Table 9: Average predicted probabilities of referrals as successful recruitment strategy.

Variable	Pred. probab.	Std. Err.	[95% Conf.	Interval]
Number of employees (4 firm size classes)				
$1 \leq ee < 10$	0.624	0.016	0.593	0.655
$10 \leq ee < 50$	0.594	0.003	0.587	0.600
$50 \leq ee < 250$	0.526	0.005	0.515	0.536
$250 \leq ee$	0.464	0.016	0.432	0.496

Note: Average predicted probabilities of referrals as successful recruitment strategy, standard errors and 95 per cent confidence intervals based on the specification estimates in column 7 in table 8.
Source: IAB Job Vacancy Survey 2012-2016. Own computations.

Another finding from table 8 is that the coefficient on unemployment status is smaller than 1. Therefore, referral hiring is more widespread among employed workers who want to change the job rather than unemployed. To investigate this result we have re-estimated the model from table 8 only for previously unemployed successful candidates.

Table 10 contains the results. Even though the sample is smaller when we consider previously unemployed candidates, this specification is closer to the theoretical model, where there is no on-the-job search. In column 2 we can see that the coefficient on the formal search index remains almost the same and it is significant, indicating that more formal search activities reduce the probability of referral hiring. Moreover, one of the firm size variables becomes insignificant once we control for the search intensity. This implies that lower probability of hiring a worker by referral is fully explained by the higher formal search intensity of larger firms with up to 250 employees. This is in line with hypothesis H5. Only for very large firms with more than 250 employees the firm size coefficient remains significant implying other factors at play which are beyond our model.

Again, we computed average predicted probabilities for referrals as successful recruitment

[11] However, this also implies that there can be additional reasons leading to the lower probability of referral hiring in larger firms which are beyond our model.

Table 10: Empirical results: Probability to recruit unemployed workers with referrals as dependent variable (y_i^S), restricted sample.

	(1) logit	(2) logit	(3) logit	(4) logit	(5) logit	(6) logit	(7) logit
Number of employees (4 firm size classes, reference: 1 ≤ ee < 10)							
10 ≤ ee < 50	0.785*		0.819	0.806	0.819	0.812	0.797
	(0.101)		(0.117)	(0.122)	(0.116)	(0.116)	(0.118)
50 ≤ ee < 250	0.635***		0.766*	0.758*	0.765*	0.756*	0.748*
	(0.088)		(0.119)	(0.118)	(0.120)	(0.116)	(0.116)
250 ≤ ee	0.369***		0.500***	0.467***	0.500***	0.497***	0.464***
	(0.073)		(0.109)	(0.106)	(0.110)	(0.107)	(0.106)
Formal search index		0.635***	0.645***	0.647***	0.645***	0.654***	0.653***
		(0.026)	(0.025)	(0.026)	(0.025)	(0.024)	(0.026)
Further control variables							
Skill requirements				x			x
Employee shares by skill level					x		x
Additional skill requirements						x	x
Observations	2,982	2,982	2,982	2,904	2,982	2,982	2,904
Pseudo R-squared	0.0254	0.0644	0.0675	0.0695	0.0675	0.0700	0.0714

Federal states cluster robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: Coefficients are reported as odds ratios, where the null effect is 1. All specifications include year dummies, dummies for the federal states where the firms are located, industrial sectors, and a dummy that indicates firms reporting both the last case of a successful and an unsuccessful recruitment case. Firms size class based on all employees, regardless whether employees are subject to social security contributions or not. Firms are considered that used both referrals and formal ways as search channels ($s_i = 1, 1 \leq a_i \leq 6$). Sample is further restricted to cases with recruitment of former unemployed. The skill requirements comprise three levels: w/o qualification (reference group), vocational training, or university degree. The employee shares by skill level comprise three groups: unskilled workers (reference group), skilled workers with vocational training, skilled workers with university degree. The additional skill requirements are a set of dummy variables that denote whether the vacancy requires leadership ability, experience, further skills from training outside formal qualification, foreign languages, and/or social skills. Detailed results on the further control variables are presented in the Appendix VI, table 21.
Source: IAB Job Vacancy Survey 2012-2016. Own computations.

strategy, now based on our preferred specification in column 7 of table 10, see table 11. We find that the probabilities of firms to successfully recruit by referral decreases with their firm size. However, the probabilities don't differ significantly, with the exception of the largest firm size class.

Table 11: Average predicted probabilities of referrals as successful recruitment strategy.

Variable	Pred. probab.	Std. Err.	[95% Conf.	Interval]
Number of employees (4 firm size classes)				
$1 \leq ee < 10$	0.564	0.029	0.508	0.620
$10 \leq ee < 50$	0.513	0.009	0.495	0.531
$50 \leq ee < 250$	0.498	0.013	0.472	0.525
$250 \leq ee$	0.391	0.035	0.322	0.459

Note: Average predicted probabilities of referrals as successful recruitment strategy, standard errors and 95 per cent confidence intervals based on the specification estimates in column 7 in table 8. Sample is restricted to cases with recruitment of former unemployed.
Source: IAB Job Vacancy Survey 2012-2016. Own computations.

Our results so far indicate that larger firms exert more effort trying to fill their vacancies in a formal way and this explains a part of the lower probability of referral hiring in larger firms. Even though the coefficient of the formal search index is statistically significant one remaining question is whether it is also meaningful from an economic perspective. Considering again table 8 we can see that the pseudo-R^2 coefficient is only 2.61 percent when we control for the firm size but not for the higher search intensity while it rises to 5.35 percent when we control for the formal search intensity but not for the firm size. This is the first indication that the search intensity index is a driving force for the lower probability of referral hiring and not the firm size per se.

To get a better notion about the relative impact of the firm size classes and the search intensity we apply a Shorrocks-Shapley decomposition (Shorrocks, 1982) of the pseudo R^2. According to this methodology, we find for the full specification in column (7) of table 8 that the firm size accounts for about 15 percent and the search intensity accounts for about 61 percent of the pseudo-R^2. We find similar results for the full specification in column (7) of table 10. Here, the firm size accounts for about 9 percent and the search intensity accounts for about 65 percent of the pseudo-R^2. We conclude that the negative relationship between referral hiring and the firm's size is to a very large extent due to the higher search effort of larger firms, which is in line with the prediction of our model related to hypothesis H5.

Finally, we test hypothesis H6, thus how firm size and the number of applicants are related. The number of applicants is clearly count data, here we particularly have to consider the distribution of these data to find the adequate model class. In doing so, we have to consider which process leads to the distribution of applications across firms. Given a population of potential applicants and after posting the vacancy, there is a certain probability that one or more workers will apply for this vacancy. We assume that the expected number of applicants increases with the duration of the vacancy. Therefore, the number of applicants per vacancy is created by a Poisson process. However, in our data the vacancies reveal very different duration times. Thus, to make the number of applicants per vacancy comparable, we decided to explore how many applicants per time unit are observed and we further assume that these numbers are the result of a Poisson process (see also the histogram in figure 5).

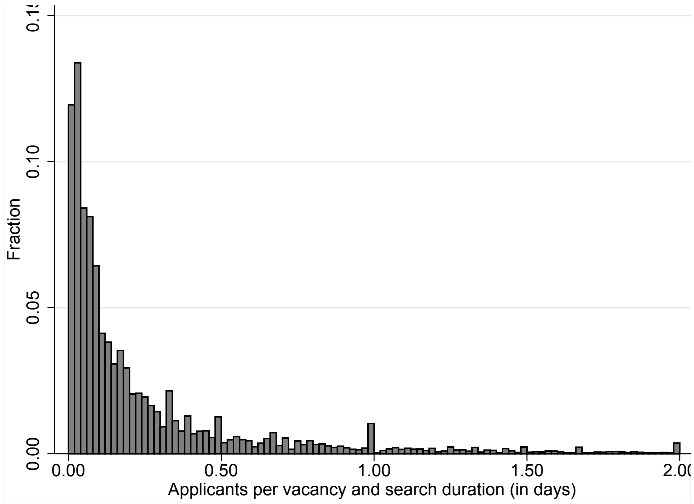

Figure 5: Distribution of the number of applicants per vacancy and search duration (fractions)

Notes: Left censored at more than 0 applicants and right censored at 2 applicants, N=25,855

Source: IAB Job Vacancy Survey 2012-2016. Own computations.

However, the Poisson process would require equality of mean and variance for the number of applicants, but the distribution here reveals clearly overdispersion with a mean of 0.44 applicants per vacancy and day with a ten-times larger variance of 4.28.

Generally a negative binomial distribution considers this. The empirical model we use is based on the Negative Binomial II distribution with the following first two moments, the expected value and the variance (Cameron/Trivedi, 2005: p. 676):

$$E[y|\mu, \alpha] = \mu \qquad Var[y|\mu, \alpha] = \mu(1 + \alpha\mu) \tag{12}$$

The variance, $Var[.]$, exceeds the mean in case $\alpha > 0$ and $\mu > 0$. To estimate the model we define μ as:

$$\mu_i \equiv y_i = \exp(b_0 + \mathbf{b_1 x_i}) \tag{13}$$

Due to the non-linearity we use maximum likelihood to estimate parameters $b_0, \mathbf{b_1}$ and α:

$$\ell_i(b_0, \mathbf{b_1}, \alpha) = \alpha^{-1} \log\left[\left(\frac{\alpha^{-1}}{\alpha^{-1} + \exp(b_0 + \mathbf{b_1 x_i})}\right] + y_i \log\left[\left(\frac{\exp(b_0 + \mathbf{b_1 x_i})}{\alpha^{-1} + \exp(b_0 + \mathbf{b_1 x_i})}\right] + \log\left[\frac{\Gamma(y_i + \alpha^{-1})}{\Gamma(\alpha^{-1})\Gamma(y_i + 1)}\right]\right(\tag{14}$$

$\Gamma(.)$ denotes the gamma function $\Gamma(r) = \int_0^\infty z^{r-1} \exp(-z)dz, r > 0$.

In this model, the dependent variable, y_i, denotes the number of applicants per vacancy and search duration. All explanatory variables are the same as before and we additionally estimate parameter α by the maximum-likelihood estimation. The estimates of the coefficients in β have to be interpreted as semi-elasticities: e.g., a one-unit change in x_i changes the conditional mean, μ_i, by the multiplier $1 + \beta_i$. Table 12 presents the main results.

The results in columns 1 to 6 are based on the unrestricted sample of firms. The results in columns 7 and 8 are based on a restricted sample where only firms are considered that reported successful recruitment cases and used both referrals and formal channels as

Table 12: Empirical results: Number of applicants per vacancy and search duration as dependent variable

	(1) Neg. Bin. II	(2) Neg. Bin. II	(3) Neg. Bin. II	(4) Neg. Bin. II	(5) Neg. Bin. II	(6) Neg. Bin. II	(7) Neg. Bin. II	(8) Neg. Bin. II
Number of employees (4 firm size classes, reference: $1 \leq ee < 10$)								
$10 \leq ee < 50$	0.321***		0.271***	0.272***	0.286***	0.292***	0.238**	0.219**
	(0.085)		(0.083)	(0.084)	(0.077)	(0.079)	(0.098)	(0.096)
$50 \leq ee < 250$	0.656***		0.547***	0.550***	0.540***	0.561***	0.608***	0.578***
	(0.104)		(0.100)	(0.100)	(0.095)	(0.096)	(0.130)	(0.129)
$250 \leq ee$	0.980***		0.836***	0.861***	0.814***	0.874***	1.049***	1.038***
	(0.096)		(0.089)	(0.093)	(0.088)	(0.088)	(0.118)	(0.116)
Formal search index		0.190***	0.142***	0.152***	0.141***	0.151***	0.095***	0.102***
		(0.015)	(0.012)	(0.012)	(0.012)	(0.011)	(0.016)	(0.016)
Further control variables								
Skill requirements				x		x	x	x
Employee shares by skill level					x	x	x	x
Additional skill requirements								x
α	0.915***	0.928***	0.897***	0.898***	0.890***	0.889***	1.011***	0.995***
	(0.085)	(0.087)	(0.081)	(0.081)	(0.081)	(0.081)	(0.132)	(0.129)
Number of observations	28,735	28,735	28,735	28,270	28,733	28,269	8,341	8,341
Pseudo R-squared	0.0601	0.0561	0.0646	0.0667	0.0671	0.0694	0.0953	0.100
Log likelihood	-23,247	-23,347	-23,137	-22,779	-23,075	-22,711	-6,501	-6,469

Federal states cluster robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: Coefficients are reported as semi-elasticities, a one-unit change in x_i changes the conditional mean, μ_i, by the multiplier $1+\beta_i$. All specifications include year dummies, dummies for the federal states where the firms are located, industrial sectors, and a dummy that indicates firms reporting both the last case of a successful and an unsuccessful recruitment case. The skill requirements comprise three levels: w/o qualification (reference group), vocational training, or university degree. The employee shares by skill level comprise three groups: unskilled workers (reference group), skilled workers with vocational training, skilled workers with university degree. The additional skill requirements are a set of dummy variables that denote whether the vacancy requires leadership ability, experience, further skills from training outside formal qualification, foreign languages, and/or social skills. Results in columns (7) and (8) are from a specification that are based on a restricted sample of firms that report successful recruitment and used both formal channels und referrals.Detailed results on the further control variables are presented in the Appendix VI, table 22.
Source: IAB Job Vacancy Survey 2012-2016. Own computations.

recruitment strategies.

Table 12 shows also that the estimates of the parameter α are significantly positive. These results confirm the overdispersion.[12]

We conclude from the results that the higher search effort of firms leads to a higher number of applications, thus, this is in line with hypothesis H6. However, even without this mechanism there are reasons why larger firms may receive more applications. For example, the literature on directed search, e.g. Moen (1997), reveals that workers anticipate higher wages in larger establishments and are more likely to send their applications to larger firms. This implies that omitting one of the two variables (firm size or search effort) in predicting the number of applications is likely to lead to the upward bias of the other variable.

Even though our model is not linear, this omitted variable bias can be observed in the first three columns of table 12. Column 1 shows that larger firms receive more applications on average, whereas column 2 shows that firms exerting more search effort also receive more applications. Column 3 with the results of a specification with both variables shows the magnitude of the effects is lower then; this suggests that the estimates of the separate effects in column 1 and column 2 are upward biased. This means that higher search effort explains a part of the positive correlation between the size of the firm and the number of applications, which confirms hypothesis H6. But the firm size coefficients remain significant, implying importance of other – unobserved – factors such as directed search.[13]

5 Further robustness checks

With our specifications in tables 5 and 6 we explored how the intensity to search via formal channels is related to the firm size and qualification requirements (see also Hypotheses H1, H2, and H3). In addition, in table 7 we analyzed how the intensity of formal search is related to the usage of referrals for worker search (see Hypothesis H4). In tables 8 and 10 we investiagted whether and how the probability to recruit with referrals is related to firm size and the intensity of search via formal channels (see also Hypothesis H5). And finally we explored how the number of applicants per vacancy and search duration is related to firm size and the intensity to search via formal channels (see Hypothesis 6).

Generally, our survey offers an alternative measure for the intensity of search via formal channels, namely, the additional costs in Euros for successful recruitment cases. We take

[12] The test statistic of α results from computing twice the difference in log-likelihoods between the negative binomial model and the Poisson model. The statistic is assumed to be χ^2- distributed with one degree of freedom. The usual asymptotic would not apply, because the Null hypothesis ($\alpha = 0$) lies on the lower bound of the parameter space ($\alpha >= 0$). However, Gutierrez/Carter/Drukker (2001) argue that the statistic should be treated as "$50 : 50$" mixture of zero and a χ^2-distribution with one degree of freedom. This test is feasible for a Poisson and Negative Binomial model with conventionally computed standard errors. We computed the test based on the specification in column 6 of table 12. According to the test statistic we have clearly to reject the Null hypothesis of $\alpha = 0$ ($\bar{\chi}_1^2 = 8122.50$, $Prob >= \bar{\chi}_1^2 = 0.000$).

[13] Our results are robust to an alternative of the presented model that is based on the Negative Binomial II distribution. This alternative is based on the so called Negative Binomial I distribution with the expectation and variance given by Cameron/Trivedi (2005: p. 676): $E[y|\mu, \delta] = \mu, \quad Var[y|\mu, \delta] = (1 + \delta)\mu$. The variance, $Var[.]$, exceeds the mean in case of $\delta > 0$ and $\mu > 0$. Details and results are presented in Appendix VII.

this measure as another proxy for the intensity of formal search under the assumption that these monetary costs are fully attributed to the formal search strategies rather than referrals. In the sample of successful recruitment cases 12,011 firms reported these additional costs and the other relevant information for our analysis.[14] Table 13 shows average additional recruiting costs by the intensity of formal search, the (successful) recruitment channel, firm size classes, and skill requirements. We see that the recruitment costs increase with the formal search intensity. Particularly, firms reported very low recruitment costs in the case when they used only referrals, only 44.66 Euros.[15] We conclude that our assumption holds that additional recruitment costs are positively associated with the formal search intensity. We can also see that the additional recruitment costs decrease for referrals as successful recruitment strategy, increase with firm size and with skill requirements. These observations are quite in line with our theoretical expectations.

Table 13: Descriptive statistics for the additional recruitment costs in Euros.

Additional recruitment costs and formal search intensity	Additional recruitment costs in Euros	
	Mean	N
Formal search intensity a_i		
0	44.66	2,188
1	490.92	3,293
2	620.61	2,978
3	1,215.90	2,194
4	2,090.47	1,009
5	3,226.22	283
6	3,279.35	66
Total	788.35	12,011

Additonal recruitment costs and successful recruitment channel	Additional recruitment costs in Euros	
	Mean	N
Recruitment way		
Formal way	1,107.60	7,531
Referrals	251.69	4,480
Total	788.35	12,011

Additonal recruitment costs and firm size	Additional recruitment costs in Euros	
	Mean	N
Number of employees(4 firm size classes)		
$1 \leq ee < 10$	281.58	1,424
$10 \leq ee < 50$	544.20	6,194
$50 \leq ee < 250$	986.50	3,115
$250 \leq ee$	2,053.38	1,278
Total	788.35	12,011

Additonal recruitment costs and firm size	Additional recruitment costs in Euros	
	Mean	N
Skill requirements		
w/o qualification	165.96	1,731
Vocational training	523.74	8,091
University degree	2,258.59	2,189
Total	788.35	12,011

Source: IAB Job Vacancy Survey 2012-2016. Own computations.

[14] In detail, the survey asked for additional recruitment costs in 2014 and 2015. In 2015, 6085 firms reported additional costs. To make these values comparable with the costs reported by 5,926 firms in 2014, we deflated the values in 2015 considering a change of consumer prices of +0.3 per cent from 2014 to 2015, compare with the press release 018 by the Federal Statistical Office from 19th January 2016 (https://www.destatis.de/EN/PressServices/Press/pr/2016/01/PE16_018_611.html).

[15] Note, that the structure of our data implies that firms exclusively use referrals in the case when they don't use formal ways for the search of workers. This means that in this case the additional recruitment costs must be linked to referrals.

Table 14 presents our results for alternative specifications with the additional recruiting costs in Euro as dependent variable and Table 15 presents results for alternative specifications with the additional recruiting costs in Euro as explanatory variable.

Table 14: Robustness checks: Ordinal least square regression to explain the additional recruiting costs in Euro as a proxy for the intensity of formal search

	(1)	(2)	(3)
	Based on a sample of firms that report only successful recruitment cases and that used		
	either referrals or both referrals and formal strategies	only formal strategies	either referrals or formal strategies or both
	$(s_i = 1, 0 \leq a_i \leq 6)$	$(s_i = 0, 1 \leq a_i \leq 6)$	$(s_i \geq 0, 0 \leq a_i \leq 6)$
	(1)	(2)	(3)
	OLS	OLS	OLS
Usage of referrals			-494.924***
			(81.853)
Number of employees (4 firm size classes, reference: 1 ≤ ee < 10)			
10 ≤ ee < 50	90.011*	242.786**	161.619***
	(48.821)	(83.750)	(44.721)
50 ≤ ee < 250	330.610***	558.925***	428.605***
	(68.986)	(109.851)	(79.324)
250 ≤ ee	913.514***	1,072.534***	1,015.058***
	(151.814)	(185.320)	(165.253)
Skill requirements, reference: w/o qualification			
Vocational training	42.110	67.316	24.578
	(35.560)	(78.876)	(34.542)
University degree	794.600***	1,629.735***	1,288.711***
	(179.518)	(161.156)	(161.305)
Further control variables			
Employee shares by skill level	x	x	x
Additional skill requirements	x	x	x
Observations	6,265	5,746	12,011
R-squared	0.075	0.154	0.123

Federal states cluster robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: The specification and the sample restriction for column (1) refer to the specification and the sample restriction in column (6) of table 5. The specification and the sample restriction for column (2) refer to the specification and the sample restriction in column (6) of table 6. The specification and the sample restriction for column (3) refer to the specification and the sample restriction in column (7) of table of table 7. All specifications include a constant, year dummies, dummies for the federal states where the firms are located, industrial sectors, and a dummy that indicates firms reporting both the last case of a successful and an unsuccessful recruitment case. Firms size class based on all employees, regardless whether employees are subject to social security contributions or not. Employee shares by skill level comprise three groups: unskilled workers, skilled workers with vocational training, skilled workers with university degree. Additional skill requirements are a set of dummy variables that denote whether the vacancy requires leadership ability, experience, further skills from training outside formal qualification, foreign languages, and/or social skills. Detailed results on the further control variables are presented in the Appendix VI, table 23.
Source: IAB Job Vacancy Survey 2012-2016. Own computations.

Column (1) of table 14 shows that the results are qualitatively similar to the results in column 6 of table 5: recruiting costs in Euros increase with the firm size and with higher skill requirements of the position. The same is true for column (2) of table 14 that refers to the specification in column (6) of table 6. Thus, these results support our findings regarding hypotheses H1, H2, and H3 from the previous section. Column (3) of table 14 confirms the results of table 7 (see column 7), that the use of referrals is negatively correlated with recruiting costs. Thus, this result supports our findings regarding hypothesis H4 from the previous section.

Columns (1) and (2) of table 15 show that the additional recruitment effort in Euros is negatively correlated with the probability to recruit with referrals – this confirms the qualitative result of the negative correlation between the formal search effort and the probability of

Table 15: Robustness checks: Specifications with additional recruiting costs in 1,000 Euros as a proxy for the intensity of formal search as explanatory variable

Dep. variable	Probability to recruit with referrals				Applicants per vacancy and search duration			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Model	logit	logit	logit	logit	Neg. Bin. II	Neg. Bin. II	Neg. Bin. II	Neg. Bin. II
Number of employees								
(4 firm size classes, reference: $1 \leq ee < 10$)								
$10 \leq$ ee < 50	0.791**	0.836*	0.649*	0.697	0.391***	0.317***	1.232	1.162
	(0.0837)	(0.0906)	(0.149)	(0.155)	(0.119)	(0.117)	(0.158)	(0.159)
$50 \leq$ ee < 250	0.590***	0.681***	0.689	0.824	0.646***	0.502***	1.855***	1.683***
	(0.0842)	(0.0999)	(0.173)	(0.215)	(0.130)	(0.137)	(0.301)	(0.285)
$250 \leq$ ee	0.371***	0.452***	0.385**	0.444*	1.175***	0.968***	3.600***	3.045***
	(0.0848)	(0.107)	(0.160)	(0.196)	(0.102)	(0.125)	(0.563)	(0.470)
Recruitment effort	0.901***	0.963**	0.824	0.910	0.0198	0.00557	1.027	1.011
(Additional costs in 1000 Euros)	(0.0263)	(0.0178)	(0.131)	(0.0874)	(0.0127)	(0.0129)	(0.0178)	(0.0179)
Formal search index		0.665***		0.713***		0.208***		1.197***
		(0.0192)		(0.0455)		(0.0242)		(0.0307)
Observations	4,077	4,077	1,030	1,030	8,216	8,216	2,940	2,940
Pseudo R-squared	0.0381	0.0713	0.0681	0.0883	0.0608	0.0702	0.107	0.112

Federal states cluster robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: The samples for the specifications in columns (1)–(8) are generally restricted to successful recruitment cases because the additional recruitment cost are only reported for successful recruitment cases. The specifications and further sample restrictions for columns (1) and (2) refer to the specification and the sample restriction in column (7) of table 8. Columns (2) and (4) additionally contain the formal search index as explanatory variable. The specifications and further sample restrictions for columns (3) and (4) refer to the specification and the sample restriction in column (7) of table 10. Coefficients in columns (1)–(4) are reported as odds ratios, where the null effect is 1. The specifications and further sample restrictions for columns (5)–(8) refer to the specifications and the sample restrictions in columns (6) and (8) of table 12. Columns (6) and (8) additionally contain the formal search index as explanatory variable. Coefficients in columns (5)–(8) are reported as semi-elasticities, a one-unit change in x_i changes the conditional mean, μ_i, by the multiplier $1+\beta_i$. More detailed results on the further control variables are presented in the Appendix VI, for columns (1)–(4) in table 24 and for columns (5)–(8) in table 25.
Source: IAB Job Vacancy Survey 2014 and 2015

referral recruitment as it was shown in table 8. In columns (3) and (4), where the specifications are based on a sample that is restricted to recruitments of former unemployed, like in table 10, the same coefficient is lower but the standard errors are larger. The magnitude of the firm size coefficients is similar to the equivalent specifications in tables 8 and 10. The firm size coefficients are also only partly significant and a comparison of the standard errors suggests that the lower number of observations leads to the loss of precision. But all in all, the results rather support our findings regarding hypothesis H5 from the previous section.

Columns (5)–(8) of table 15 show that the coefficients of the additional recruitment efforts are insignificant; even if the point estimates suggest a positive correlation with the number of applicants per vacancy and search duration. The specifications in columns (2), (4), (6), and (8) of table 15 additionally contain the formal search index. We included this variable to see how the coefficient estimates change in the case when both the additional recruitment costs and the formal search index are considered as explanatory variables. We see a weaker impact of additional recruitment costs after including the formal search index, whereas the influence of the formal search index remains robust and positive.

All in all, using additional recruitment efforts in Euros as an alternative proxy for the formal search effort does not contradict our results in the main analysis. However, our regression models based on the additional recruitment efforts in Euros suffer from a smaller number of observations and, therefore, a loss of precision. Another implication of the results above is that the formal effort of human resource managers and their actions are relatively more important in generating new applicants than additional monetary expenses. Finally, we want to note that monetary expenses for recruitement depend on prices that could be different across regions, which renders this variable less suitable for comparing heterogeneous firms. On the contrary, the formal search index is constructed based on the actions of human resource managers and is better comparable across firms. However, the identification of further components that fully describe workers' and firms' search effort goes widely beyond this paper and we have to leave these tasks for future research.

6 Conclusions

This study explores the relationship between firms' characteristics and their recruitment strategies. These strategies include a formal search channel that comprises, beside others, advertisements in newspapers and magazines, internet postings or the use of employment agencies and an informal search channel, i.e. referrals by incumbent employees. The formal search channel and the referral search induce different costs in terms of money and time; generally, the formal channel is more expensive than the informal channel. More productive firms have larger human, financial and material resources, relative to less productive firms. Therefore, more productive firms can spend more resources on formal search to attract job applicants. This implies that firm characteristics are important for understanding firms' choices of recruiting channels.

We propose a model based on a search and matching framework with two search channels, the formal and the informal channel. In contrast to previous studies there is a continuum of heterogeneous vacancies in our model where every firm with an open vacancy chooses an optimal search effort in order to attract job candidates. Workers send simultaneous applications to open positions. Similar to the previous studies we prove that firm size and productivity are positively correlated. This finding is important for our empirical assessment because there is a lack of (representative) data with valid information on individual firm productivity and recruitment strategies.

We derive six hypotheses based on the model: (1) Larger firms invest more effort into formal search activities; (2) Firms invest more formal search effort in labour markets for more educated workers; (3) The positive relationship between firm size and formal search intensity should be observed even for firms that don't use referrals; (4) Firms that use referrals as a search channel invest less into formal search compared to firms that don't use referrals; (5) Larger firms are less likely to hire an applicant by referral than smaller firms and (6) More intensive search effort leads to a larger number of applications.

We assess these hypotheses by using the IAB Job Vacancy Survey (IAB JVS). The IAB JVS is a representative survey among human resource managers and managing directors in German firms reporting information about their search strategies with detailed answers about the most recent successful and the most recent unsuccessful recruitment case. Since most firms are observed only once, our sample is a repeated cross-section of firms and includes more than 42,000 observations over the period 2012-2016.

To obtain an empirical proxy for the intensity of formal job search we define an ordinal variable equal to the number of formal search activities used by the firm. The list of such activities includes placed ads in newspapers or magazines, posted vacancy in the internet, posted vacancy on the firm's own website, contacted the federal employment agency, contacted a private employment agency, and considered the pool of unsolicited applications. Because of the ordinal nature of this index variable we use an ordinal logistic regression with time-fixed effects.

Our empirical results confirm the six hypotheses derived from our model. More generally, we show that firm characteristics and requirements of posted vacancies, like skill requirements, are central to understand the firms' choice of search channels. For example, we find that firms are less likely to use formal search if they need an applicant with leadership abilities or large experience. In addition, our analysis reveals that unemployed workers are more likely to enter employment through one of the formal channels whereas employed workers changing jobs are more likely to be hired by referrals.

There are two issues that we consider as important for future research. First, our theoretical model does not consider the intensity of referral use. Second, as we can see from the data, there is more than one formal activity that firms undertake to find new workers. In our model we merge these activities into one formal channel, thus it is a task for future research to isolate these activities and investigate their efficiency.

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A Appendix

Appendix I: Proof of proposition 1.

Opening the square bracket in equation (3) yields:

$$\frac{0.5c_0q^2(\theta)(1-\beta)^2}{(r+\delta)^2}r^2V^2(p) - V(p)\Big[\frac{0.5c_0q^2(\theta)(1-\beta)^2}{(r+\delta)^2}2ry(p) + \frac{q^N(u)(1-\beta)}{r+\delta}r + r + \phi\Big]$$
$$+ \quad \frac{0.5c_0q^2(\theta)(1-\beta)^2}{(r+\delta)^2}y^2(p) + \frac{q^N(u)(1-\beta)}{r+\delta}y(p) = 0$$

Using the definition of variables $A(\theta)$ and $q^N(u)$ this equation can be rewritten as:

$$A(\theta)r^2V^2(p) - V(p)[A(\theta)2ry(p) + B(u)r + r + \phi] + A(\theta)y^2(p) + B(u)y(p) = 0$$

The discriminant of this quadratic equation is given by:

$$\begin{aligned} D &= [A(\theta)2ry(p) + B(u)r + r + \phi]^2 - 4A(\theta)r^2[A(\theta)y^2(p) + B(u)y(p)] \\ &= 4A^2(\theta)r^2y^2(p) + 4A(\theta)ry(p)(B(u)r + r + \phi) + (B(u)r + r + \phi)^2 \\ &- 4A^2(\theta)r^2y^2(p) - 4A(\theta)r^2B(u)y(p) = (B(u)r + r + \phi)^2 + 4A(\theta)ry(p)(r + \phi) \end{aligned}$$

This equation has two roots, however, the upper root exceeds $y(p)/r$ and can not be the equilibrium solution. So we get:

$$V(p) = \frac{A(\theta)2ry(p) + B(u)r + r + \phi - \sqrt{(B(u)r + r + \phi)^2 + 4A(\theta)ry(p)(r + \phi)}}{2A(\theta)r^2}$$

so that $rV(p)$ is given by:

$$rV(p) = y(p) - \frac{1}{2A(\theta)r}\Big[\sqrt{(B(u)r + r + \phi)^2 + 4A(\theta)ry(p)(r + \phi)} - (B(u)r + r + \phi)\Big]\Big(< y(p)$$

Differentiating $rV(p)$ with respect to $y(p)$ we obtain:

$$\begin{aligned} \frac{\partial rV(p)}{\partial y(p)} &= 1 - \frac{4rA(\theta)(r + \phi)}{4rA(\theta)\sqrt{(B(u)r + r + \phi)^2 + 4A(\theta)ry(p)(r + \phi)}} \\ &= 1 - \frac{r + \phi}{\sqrt{(r + \phi)^2 + 2rB(u)(r + \phi) + r^2B^2(u) + 4A(\theta)ry(p)(r + \phi)}} > 0 \end{aligned}$$

Differentiating $rV(p)$ with respect to $A(\theta)$ we obtain:

$$\begin{aligned} \frac{\partial rV(p)}{\partial A(\theta)} &= \frac{1}{2rA^2(\theta)}\Big[\sqrt{(B(u)r + r + \phi)^2 + 4A(\theta)ry(p)(r + \phi)} - (B(u)r + r + \phi)\Big] \\ &- \frac{4ry(p)(r + \phi)}{4rA(\theta)\sqrt{(B(u)r + r + \phi)^2 + 4A(\theta)ry(p)(r + \phi)}} \\ &= \frac{(B(u)r + r + \phi)^2 + 4A(\theta)ry(p)(r + \phi) - 2rA(\theta)y(p)(r + \phi)}{2rA^2(\theta)\sqrt{(B(u)r + r + \phi)^2 + 4A(\theta)ry(p)(r + \phi)}} \\ &- \frac{(B(u)r + r + \phi)\sqrt{(B(u)r + r + \phi)^2 + 4A(\theta)ry(p)(r + \phi)}}{2rA^2(\theta)\sqrt{(B(u)r + r + \phi)^2 + 4A(\theta)ry(p)(r + \phi)}} \end{aligned}$$

The denominator of this expression $2rA^2(\theta)\sqrt{(B(u)r + r + \phi)^2 + 4A(\theta)ry(p)(r + \phi)}$ is positive, so we focus on the analysis of the numerator, which is given by:

$$
\begin{aligned}
- & \quad (B(u)r + r + \phi)\sqrt{(B(u)r + r + \phi)^2 + 4A(\theta)ry(p)(r + \phi)} + (B(u)r + r + \phi)^2 + 2A(\theta)ry(p)(r + \phi) \\
= & \quad -\sqrt{(B(u)r + r + \phi)^4 + 4A(\theta)ry(p)(r + \phi)(B(u)r + r + \phi)^2 \pm [2rA(\theta)y(p)(r + \phi)]^2} \\
+ & \quad (B(u)r + r + \phi)^2 + 2A(\theta)ry(p)(r + \phi) \\
= & \quad -\sqrt{[(B(u)r + r + \phi)^2 + 2rA(\theta)y(p)(r + \phi)]^2 - [2rA(\theta)y(p)(r + \phi)]^2} \\
+ & \quad (B(u)r + r + \phi)^2 + 2A(\theta)ry(p)(r + \phi) > 0
\end{aligned}
$$

which means that $\partial rV(p)/\partial A(\theta) > 0$. Next we consider the derivative of $rV(p)$ with respect to $B(u)$:

$$
\begin{aligned}
\frac{rV(p)}{B(u)} &= \frac{1}{2rA(\theta)}\left(r - \frac{2r(rB + r + \phi)}{2\sqrt{(B(u)r + r + \phi)^2 + 4A(\theta)ry(p)(r + \phi)}}\right) \\
&= \frac{1}{2A(\theta)}\frac{\sqrt{(B(u)r + r + \phi)^2 + 4A(\theta)ry(p)(r + \phi)} - (B(u)r + r + \phi)}{\sqrt{(B(u)r + r + \phi)^2 + 4A(\theta)ry(p)(r + \phi)}} > 0
\end{aligned}
$$

Finally, we consider the limiting case when $\theta \to 0$, which means that $q(\theta) \to \infty$ and $A(\theta) \to \infty$. We get:

$$
\lim_{A(\theta)\to\infty} rV(p) = y(p) - \lim_{A(\theta)\to\infty} \frac{1}{2r}\left[\left(\sqrt{\frac{(B(u)r + r + \phi)^2}{A^2(\theta)} + \frac{4ry(p)(r + \phi)}{A(\theta)}} - \frac{(B(u)r + r + \phi)}{A(\theta)}\right]\right) = y(p)
$$

which completes the proof of proposition 1.

Appendix II: proof of proposition 2. Insert $V(p)$ into the equation for $a(p)$ to get:

$$
\begin{aligned}
a(p) &= c_0 q(\theta)(J(p) - V(p)) = \frac{c_0 q(\theta)(1 - \beta)}{r + \delta}(y(p) - rV(p)) = \\
&= \frac{c_0 q(\theta)(1 - \beta)}{(r + \delta)2rA(\theta)}\left[\sqrt{(B(u)r + r + \phi)^2 + 4A(\theta)ry(p)(r + \phi)} - (B(u)r + r + \phi)\right] \\
&= \frac{(r + \delta)}{rq(\theta)(1 - \beta)}\left[\sqrt{(B(u)r + r + \phi)^2 + 4A(\theta)ry(p)(r + \phi)} - (B(u)r + r + \phi)\right] \\
&= \frac{(r + \delta)}{r(1 - \beta)}\left[\left(\sqrt{\frac{(B(u)r + r + \phi)^2}{q^2(\theta)} + \frac{2ry(p)(r + \phi)c_0(1 - \beta)^2}{(r + \delta)^2}} - \frac{(B(u)r + r + \phi)}{q(\theta)}\right]\right)
\end{aligned}
$$

Let $X = (B(u)r + r + \phi)/q(\theta)$, obviously X is increasing in $B(u)$ but decreasing in $q(\theta)$. Search intensity $a(p)$ can then be rewritten as:

$$
a(p) = \frac{(r + \delta)}{r(1 - \beta)}\left[\left(\sqrt{X^2 + \frac{2ry(p)(r + \phi)c_0(1 - \beta)^2}{(r + \delta)^2}} - X\right]\right)
$$

Differentiating $a(p)$ with respect to X we get:

$$
\begin{aligned}
\frac{\partial a(p)}{\partial X} &= \frac{(r + \delta)}{r(1 - \beta)}\left(\frac{2X}{2\sqrt{X^2 + \frac{2ry(p)(r+\phi)c_0(1-\beta)^2}{(r+\delta)^2}}} - 1\right) \\
&= \frac{(r + \delta)}{r(1 - \beta)}\frac{X - \sqrt{X^2 + \frac{2ry(p)(r+\phi)c_0(1-\beta)^2}{(r+\delta)^2}}}{\sqrt{X^2 + \frac{2ry(p)(r+\phi)c_0(1-\beta)^2}{(r+\delta)^2}}}\Bigg) < 0
\end{aligned}
$$

This means that $\partial a(p)/\partial B(u) < 0$ and $\partial a(p)/\partial q(\theta) > 0$.

Appendix III: Proof of proposition 3.

Rewrite equation for y_0 as follows:

$$A(\theta)y_0^2 - y_0(2rKA(\theta) - B(u)) + A(\theta)r^2K^2 - K(rB + r + \phi) = 0$$

The discriminant of this quadratic equation is:

$$\begin{aligned} D &= (2rKA(\theta) - B(u))^2 - 4A(\theta)(A(\theta)r^2K^2 - K(rB(u) + r + \phi)) \\ &= 4r^2K^2A^2(\theta) - 4rKA(\theta)B(u) + B^2(u) - 4A^2(\theta)r^2K^2 + 4A(\theta)KrB(u) + 4A(\theta)K(r + \phi) \\ &= B^2(u) + 4A(\theta)K(r + \phi) \end{aligned}$$

This equation has two roots, however, the lower root is less than rK which can nor be an equilibrium outcome. This yields:

$$\begin{aligned} y_0(\theta, u) &= \frac{2rKA(\theta) - B(u) + \sqrt{B^2(u) + 4A(\theta)K(r + \phi)}}{2A(\theta)} \\ &= rK + \frac{1}{2A(\theta)}\Big(\sqrt{B^2(u) + 4A(\theta)K(r + \phi)} - B(u)\Big) \\ &= rK + \frac{(r+\delta)^2}{c_0q^2(\theta)(1-\beta)^2}\Big(\sqrt{\frac{(q^N(u))^2(1-\beta)^2}{(r+\delta)^2} + \frac{2K(r+\phi)c_0q^2(\theta)(1-\beta)^2}{(r+\delta^2)}} - \frac{q^N(u)(1-\beta)}{r+\delta}\Big) \\ &= rK + \frac{r+\delta}{c_0q^2(\theta)(1-\beta)}\Big(\sqrt{q^N(u)^2 + 2K(r+\phi)c_0q^2(\theta)} - q^N(u)\Big) \end{aligned}$$

Differentiating $y_0(\theta, u)$ with respect to $A(\theta)$ we get:

$$\begin{aligned} \frac{\partial y_0(\theta, u)}{\partial A(\theta)} &= -\frac{\sqrt{B^2(u) + 4A(\theta)K(r+\phi)} - B(u)}{2A^2(\theta)} + \frac{1}{2A(\theta)}\frac{4K(r+\phi)}{2\sqrt{B^2(u) + 4A(\theta)K(r+\phi)}} \\ &= \frac{-(B^2(u) + 4A(\theta)K(r+\phi)) + B(u)\sqrt{B^2(u) + 4A(\theta)K(r+\phi)} + 2KA(\theta)(r+\phi)}{2A(\theta^2)\sqrt{B^2(u) + 4A(\theta)K(r+\phi)}} \end{aligned}$$

Since the denominator is positive, we continue analyzing the sign of the numerator:

$$\begin{aligned} &\sqrt{B^4(u) + 4A(\theta)K(r+\phi)B^2(u)} - (B^2(u) + 2A(\theta)K(r+\phi)) \\ =\ &\sqrt{B^4(u) + 4A(\theta)K(r+\phi)B^2(u) \pm (2A(\theta)K(r+\phi))^2} - (B^2(u) + 2A(\theta)K(r+\phi)) \\ =\ &\sqrt{(B^2(u) + 2A(\theta)K(r+\phi))^2 - (2A(\theta)K(r+\phi))^2} - (B^2(u) + 2A(\theta)K(r+\phi)) < 0 \end{aligned}$$

This means that $\partial y_0(\theta, u)/\partial A(\theta) < 0$. Next we differentiate $y_0(\theta, u)$ with respect to $B(u)$:

$$\begin{aligned} \frac{\partial y_0(\theta, u)}{\partial B(u)} &= \frac{1}{2A(\theta)}\Big(\frac{2B(u)}{2\sqrt{B^2(u) + 4A(\theta)K(r+\phi)}} - 1\Big) \\ &= \frac{1}{2A(\theta)}\Big(\frac{B(u) - \sqrt{B^2(u) + 4A(\theta)K(r+\phi)}}{\sqrt{B^2(u) + 4A(\theta)K(r+\phi)}}\Big) < 0 \end{aligned}$$

And finally we consider the limiting case when $\theta \to 0$:

$$\lim_{\theta\to 0} y_0(\theta,u) = \lim_{A(\theta)\to\infty} y_0(\theta) = rK + \frac{1}{2}\sqrt{\left(\left(\frac{B(u)}{A(\theta)}\right)^2 + \frac{4K(r+\phi)}{A(\theta)}\right.} - \frac{B(u)}{A(\theta)}\Bigg) = rK$$

Appendix IV: To obtain solution of equation (7) rewrite it as:

$$\gamma y_0^2 - 2\gamma y_0 rK + \gamma r^2 k^2 + 2r^2 bK - \gamma(b - \bar{w} - rK)^2 = 0$$

The discriminant of this equation is given by:

$$\begin{aligned} D &= 4\gamma^2 r^2 K^2 - 4\gamma(\gamma r^2 k^2 + 2r^2 bK - \gamma(b - \bar{w} - rK)^2) \\ &= 4\gamma^2(b - \bar{w} - rK)^2 - 8\gamma r^2 bK^2 \end{aligned}$$

so the two roots are given by:

$$y_0^{(1)} = rK - \sqrt{(b - \bar{w} - rK)^2 - \frac{2r^2 bK}{\gamma}} < rK \qquad y_0^{(2)} = rK + \sqrt{(b - \bar{w} - rK)^2 - \frac{2r^2 bK}{\gamma}} > rK$$

Appendix V: Endogenizing the reservation wage $\bar{w}$. Consider some worker employed in a firm with productivity p and wage $w(p)$. The present value of employment for this worker is given by:

$$rW(p) = w(p) - \delta(W(p) - U)$$

where U is a present value of unemployment, which can be written as:

$$rU = z + \int_{p_0}^{1} \frac{m(u,\tilde{v})}{\tilde{v}} \frac{a(p)v(p)}{\tilde{v}}(W(p) - U)dF(p) + \int_{p_0}^{1} \frac{q^N(u)v}{u} \frac{v(p)}{v}(W(p) - U)dF(p)$$

Here z is the flow unemployment benefit, the first term is the job arrival rate via the formal channel $m(u,\tilde{v})/\tilde{v}$ multiplied by the expected value gain $W(p) - U$ and the last term on the right-hand side is the job-finding rate via referrals $q^N(u)v/u$ multiplied by the expected value gain. Taking into account that $m(u,\tilde{v})/\tilde{v} = m(1,\theta^*(u))$ and the uniform distribution we get:

$$rU = z + m(1,\theta^*(u)) \int_{p_0}^{1} \frac{a(p)v(p)}{\tilde{v}}(W(p) - U)dp + \frac{q^N(u)v}{u} \int_{p_0}^{1} \frac{v(p)}{v}(W(p) - U)dp$$

Given that $W(p) - U = (w(p) - rU)/(r + \delta)$, we can see that rU is the reservation wage of workers, that is $rU = \bar{w}$, so the reservation wage $\bar{w}$ can be found as:

$$\bar{w} = z + m(1,\theta^*(u))\beta \int_{p_0}^{1} \frac{a(p)v(p)}{\tilde{v}} \frac{(bp - rV(p) - \bar{w})}{r + \delta} dp + \frac{q^N(u)v}{u}\beta \int_{p_0}^{1} \frac{v(p)}{v} \frac{(bp - rV(p) - \bar{w})}{r + \delta} dp$$

Given that with uniform distribution $v(p)/v = f(p)/(1 - F(p_0)) = b/(b - y_0^*(u) - \bar{w})$ we get:

$$\bar{w} = z + m(1,\theta^*(u))\frac{b\beta}{r + \delta} \int_{p_0}^{1} \frac{a(p)v}{\tilde{v}} \frac{(bp - rV(p) - \bar{w})}{(b - y_0^*(u) - \bar{w})} dp + \frac{q^N(u)v}{u} \frac{b\beta}{r + \delta} \int_{p_0}^{1} \frac{(bp - rV(p) - \bar{w})}{(b - y_0^*(u) - \bar{w})} dp$$

Finally, combining the two terms on the right-hand side, taking into account that $p_0 =$

$(y_0^*(u) + \bar{w})/b$ and $\tilde{v}/v = \bar{a}(u)$ we get:

$$\bar{w} = z + \frac{b\beta}{r+\delta} \int_{(y_0^*(u)+\bar{w})/b}^{1} \frac{(bp - rV(p) - \bar{w})}{(b - y_0^*(u) - \bar{w})} \Big(m(1, \theta^*(u)) \frac{a(p)}{\bar{a}(u)} + \frac{q^N(u)v}{u} \Big) dp$$

Appendix VI: Tables with detailed results.

Table 16: Detailed empirical results of table 3: Probability of using the formal channel in recruiting processes as dependent variable, $Prob(y_i^F = 1)$

	All observations				Only successful recruitment cases	
	(1)	(2)	(3)	(4)	(5)	(6)
	logit	logit	logit	logit	logit	logit
Number of employees (4 firm size classes, reference: 1 ≤ ee < 10)						
10 ≤ ee < 50	1.938***		1.888***	1.898***	2.169***	2.177***
	(0.073)		(0.074)	(0.073)	(0.097)	(0.096)
50 ≤ ee < 250	4.357***		4.172***	4.212***	4.932***	4.940***
	(0.303)		(0.301)	(0.308)	(0.378)	(0.383)
250 ≤ ee	9.680***		8.709***	8.868***	10.503***	10.368***
	(0.799)		(0.673)	(0.688)	(0.920)	(0.897)
Skill requirements, reference: w/o qualification						
Vocational training		1.839***	1.772***	1.717***	1.658***	1.613***
		(0.083)	(0.082)	(0.080)	(0.076)	(0.076)
University degree		2.935***	2.220***	1.976***	1.847***	1.814***
		(0.184)	(0.125)	(0.104)	(0.097)	(0.096)
Employee shares by skill level, reference: share of unskilled workers						
Share of skilled workers with vocational training				1.179	1.165	1.161
				(0.124)	(0.129)	(0.128)
Share of skilled workers with university degree				1.665***	1.757***	1.671***
				(0.233)	(0.236)	(0.230)
Additional skill requirements						
Leadership ability						0.747***
						(0.048)
Experience						0.928**
						(0.031)
Further skills from training						1.172***
outside formal qualification						(0.042)
Foreign lang.						1.082**
						(0.040)
Social skills						1.261***
						(0.034)
Observations	43,378	42,113	42,113	42,112	34,706	34,706
Pseudo R-squared	0.101	0.0673	0.107	0.108	0.101	0.104

Federal states cluster robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: Coefficients are reported as odds ratios, where a zero effect is 1. All specifications include year dummies, dummies for the federal states where the firms are located, industrial sectors, and a dummy that indicates firms reporting both the last case of a successful and an unsuccessful recruitment case. Firms size class based on all employees, regardless whether employees are subject to social security contributions or not. Firms are considered that used exclusively referrals, exclusively formal ways, or both referrals and formal ways as search channels ($s_i \geq 0, 0 \leq a_i \leq 6$).
Source: IAB Job Vacancy Survey 2012-2016. Own computations.

Table 17: Detailed empirical results of table 5: Search intensity in formal ways, a_i, as dependent variable.

	All observations				Only successful recruitment cases	
	(1)	(2)	(3)	(4)	(5)	(6)
	ord. logit	ord. logit	ord. logit	ord. logit	ord. logit	ord. logit
Number of employees (4 firm size classes, reference: 1 ≤ ee < 10)						
10 ≤ ee < 50	1.775***		1.728***	1.737***	2.029***	2.041***
	(0.054)		(0.053)	(0.052)	(0.066)	(0.067)
50 ≤ ee < 250	3.424***		3.289***	3.304***	4.038***	4.051***
	(0.144)		(0.136)	(0.139)	(0.204)	(0.208)
250 ≤ ee	6.252***		5.688***	5.742***	7.385***	7.326***
	(0.375)		(0.325)	(0.345)	(0.479)	(0.507)
Skill requirements, reference: w/o qualification						
Vocational training		1.593***	1.561***	1.554***	1.487***	1.415***
		(0.065)	(0.072)	(0.072)	(0.066)	(0.062)
University degree		2.470***	1.975***	1.868***	1.721***	1.611***
		(0.131)	(0.111)	(0.109)	(0.115)	(0.111)
Employee shares by skill level, reference: share of unskilled workers						
Share of skilled workers with vocational training				1.000	0.939	0.933
				(0.083)	(0.065)	(0.067)
Share of skilled workers with university degree				1.232*	1.261**	1.226*
				(0.143)	(0.147)	(0.147)
Additional skill requirements						
Leadership ability						0.829***
						(0.031)
Experience						0.926***
						(0.026)
Further skills from training outside formal qualification						1.274***
						(0.041)
Foreign lang.						1.019
						(0.043)
Social skills						1.279***
						(0.048)
Observations	22,828	22,137	22,137	22,137	17,696	17,696
Pseudo R-squared	0.0604	0.0433	0.0625	0.0626	0.0573	0.0594

Federal states cluster robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: Coefficients are reported as odds ratios, where the null effect is 1. All specifications include year dummies, dummies for the federal states where the firms are located, industrial sectors, and a dummy that indicates firms reporting both the last case of a successful and an unsuccessful recruitment case. Firms size class based on all employees, regardless whether employees are subject to social security contributions or not. Firms are considered that used exclusively referrals or both referrals and formal ways as search channels ($s_i = 1, 0 \leq a_i \leq 6$).
Estimated cutpoints for specification in column (4):
$\kappa_0 = 1.415615$, $\kappa_1 = 2.483963$, $\kappa_2 = 3.568742$, $\kappa_3 = 4.740601$, $\kappa_4 = 6.289588$, $\kappa_5 = 7.893848$
Source: IAB Job Vacancy Survey 2012-2016. Own computations.

Table 18: Detailed empirical results of table 6: Search intensity in formal ways as dependent variable, a_i, restricted sample.

	All observations				Only successful recruitment cases	
	(1)	(2)	(3)	(4)	(5)	(6)
	ord. logit	ord. logit	ord. logit	ord. logit	ord. logit	ord. logit
Number of employees (4 firm size classes, reference: 1 ≤ ee < 10)						
10 ≤ ee < 50	1.403***		1.348***	1.349***	1.404***	1.413***
	(0.057)		(0.051)	(0.052)	(0.065)	(0.067)
50 ≤ ee < 250	2.362***		2.200***	2.202***	2.274***	2.271***
	(0.111)		(0.109)	(0.113)	(0.128)	(0.127)
250 ≤ ee	3.647***		3.135***	3.136***	3.154***	3.121***
	(0.290)		(0.240)	(0.250)	(0.262)	(0.257)
Skill requirements, reference: w/o qualification						
Vocational training		1.902***	1.871***	1.864***	1.868***	1.694***
		(0.142)	(0.133)	(0.130)	(0.130)	(0.119)
University degree		3.134***	2.601***	2.581***	2.583***	2.232***
		(0.261)	(0.184)	(0.217)	(0.219)	(0.192)
Employee shares by skill level, reference: share of unskilled workers						
Share of skilled workers with vocational training				1.025	0.986	0.993
				(0.115)	(0.122)	(0.123)
Share of skilled workers with university degree				1.044	1.035	1.036
				(0.156)	(0.171)	(0.171)
Additional skill requirements						
Leadership ability						0.996
						(0.069)
Experience						1.156***
						(0.043)
Further skills from training outside formal qualification						1.193***
						(0.048)
Foreign lang.						0.983
						(0.069)
Social skills						1.199***
						(0.024)
Observations	20,550	19,976	19,976	19,975	17,010	17,010
Pseudo R-squared	0.0304	0.0241	0.0362	0.0362	0.0357	0.0384

Federal states cluster robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: Coefficients are reported as odds ratios, where the null effect is 1. All specifications include year dummies, dummies for the federal states where the firms are located, industrial sectors, and a dummy that indicates firms reporting both the last case of a successful and an unsuccessful recruitment case. Firms size class based on all employees, regardless whether employees are subject to social security contributions or not. Firms are considered that used exclusively formal ways as search channels ($s_i = 0, 1 \leq a_i \leq 6$).
Estimated cutpoints for specification in column (4):
$\kappa_1 = 1.114071$, $\kappa_2 = 2.551012$, $\kappa_3 = 4.075527$, $\kappa_4 = 6.015036$, $\kappa_5 = 8.273729$
Source: IAB Job Vacancy Survey 2012-2016. Own computations.

Table 19: Detailed empirical results of table 7: Search intensity in formal ways, a_i, and the usage of referrals.

	All observations					Only successful recruitment cases	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	ord. logit	ord. logit	ord. logit	ord. logit	ord. logit	ord. logit	ord. logit
Usage of referrals	0.413***	0.449***	0.431***	0.462***	0.462***	0.388***	0.385***
	(0.015)	(0.017)	(0.017)	(0.018)	(0.018)	(0.014)	(0.014)
Number of employees (4 firm size classes, reference: 1 ≤ ee < 10)							
10 ≤ ee < 50		1.701***		1.650***	1.654***	1.843***	1.852***
		(0.047)		(0.045)	(0.045)	(0.057)	(0.057)
50 ≤ ee < 250		3.090***		2.932***	2.938***	3.303***	3.303***
		(0.114)		(0.108)	(0.112)	(0.139)	(0.134)
250 ≤ ee		4.843***		4.296***	4.309***	4.812***	4.760***
		(0.252)		(0.193)	(0.206)	(0.262)	(0.255)
Skill requirements, reference: w/o qualification							
Vocational training			1.718***	1.680***	1.676***	1.603***	1.494***
			(0.075)	(0.077)	(0.076)	(0.075)	(0.067)
University degree			2.725***	2.200***	2.137***	2.005***	1.812***
			(0.152)	(0.107)	(0.115)	(0.108)	(0.097)
Employee shares by skill level, reference: share of unskilled workers							
Share of skilled workers with vocational training					0.997	0.976	0.973
					(0.085)	(0.075)	(0.075)
Share of skilled workers with university degree					1.133	1.173	1.144
					(0.123)	(0.125)	(0.124)
Additional skill requirements							
Leadership ability							0.901***
							(0.029)
Experience							1.014
							(0.025)
Further skills from training outside formal qualification							1.237***
							(0.035)
Foreign lang.							1.022
							(0.053)
Social skills							1.241***
							(0.032)
Observations	43,378	43,378	42,113	42,113	42,112	34,706	34,706
Pseudo R-squared	0.0426	0.0604	0.0481	0.0632	0.0632	0.0679	0.0698

Federal states cluster robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: Coefficients are reported as odds ratios, where the null effect is 1. All specifications include year dummies, dummies for the federal states where the firms are located, industrial sectors, and a dummy that indicates firms reporting both the last case of a successful and an unsuccessful recruitment case. Firms size class based on all employees, regardless whether employees are subject to social security contributions or not. Firms are considered that used both or either exclusively formal ways or referrals as search channels ($s_i \geq 0, 0 \leq a_i \leq 6$).
Estimated cutpoints for specification in column (5):
$\kappa_1 = .0026124$, $\kappa_2 = 1.614542$, $\kappa_3 = 2.873646$, $\kappa_4 = 4.226648$, $\kappa_5 = 5.932604$, $\kappa_6 = 7.724602$
Source: IAB Job Vacancy Survey 2012-2016. Own computations.

Table 20: Detailed empirical results of table 8: Probability to recruit with referrals as dependent variable (y_i^S)

	(1) logit	(2) logit	(3) logit	(4) logit	(5) logit	(6) logit	(7) logit
Number of employees (4 firm size classes, reference: 1 ≤ ee < 10)							
10 ≤ ee < 50	0.826***		0.873**	0.878*	0.869**	0.871**	0.872*
	(0.051)		(0.059)	(0.064)	(0.059)	(0.060)	(0.063)
50 ≤ ee < 250	0.552***		0.646***	0.651***	0.645***	0.646***	0.648***
	(0.042)		(0.057)	(0.059)	(0.058)	(0.057)	(0.058)
250 ≤ ee	0.372***		0.490***	0.500***	0.491***	0.494***	0.497***
	(0.040)		(0.058)	(0.062)	(0.059)	(0.057)	(0.062)
Formal search index		0.658***	0.677***	0.681***	0.678***	0.678***	0.680***
		(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
Skill requirements, reference: w/o qualification							
Vocational training				0.886**			0.891*
				(0.054)			(0.061)
University degree				0.807***			0.876*
				(0.064)			(0.069)
Employee shares by skill level, reference: share of unskilled workers							
Share of skilled workers with vocational training					0.972		1.050
					(0.129)		(0.140)
Share of skilled workers with university degree					0.698**		0.815
					(0.114)		(0.130)
Additional skill requirements							
Leadership ability						1.190***	1.222***
						(0.069)	(0.078)
Experience						1.036	1.045
						(0.057)	(0.062)
Further skills from training outside formal qualification						1.047	1.045
						(0.036)	(0.032)
Foreign lang.						0.855*	0.883*
						(0.070)	(0.066)
Social skills						0.832***	0.846***
						(0.035)	(0.036)
Former employment status, reference: out of labor force							
unemployed	0.608***	0.634***	0.627***	0.610***	0.623***	0.623***	0.607***
	(0.049)	(0.051)	(0.050)	(0.053)	(0.049)	(0.049)	(0.052)
employed	0.894**	0.915	0.943	0.950	0.944	0.943	0.946
	(0.050)	(0.050)	(0.051)	(0.057)	(0.051)	(0.051)	(0.056)
Observations	11,883	11,883	11,883	11,578	11,883	11,883	11,578
Pseudo R-squared	0.0261	0.0535	0.0602	0.0607	0.0609	0.0618	0.0624

Federal states cluster robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: Coefficients are reported as odds ratios, where the null effect is 1. All specifications include year dummies, dummies for the federal states where the firms are located, industrial sectors, and a dummy that indicates firms reporting both the last case of a successful and an unsuccessful recruitment case. Firms size class based on all employees, regardless whether employees are subject to social security contributions or not. Firms are considered that used both referrals and formal ways as search channels ($s_i = 1, 1 \leq a_i \leq 6$).
Source: IAB Job Vacancy Survey 2012-2016. Own computations.

Table 21: Detailed empirical results of table 10: Probability to recruit unemployed workers with referrals as dependent variable (y_i^S), restricted sample.

	(1) logit	(2) logit	(3) logit	(4) logit	(5) logit	(6) logit	(7) logit
Number of employees (4 firm size classes, reference: 1 ≤ ee < 10)							
10 ≤ ee < 50	0.785*		0.819	0.806	0.819	0.812	0.797
	(0.101)		(0.117)	(0.122)	(0.116)	(0.116)	(0.118)
50 ≤ ee < 250	0.635***		0.766*	0.758*	0.765*	0.756*	0.748*
	(0.088)		(0.119)	(0.118)	(0.120)	(0.116)	(0.116)
250 ≤ ee	0.369***		0.500***	0.467***	0.500***	0.497***	0.464***
	(0.073)		(0.109)	(0.106)	(0.110)	(0.107)	(0.106)
Formal search index		0.635***	0.645***	0.647***	0.645***	0.654***	0.653***
		(0.026)	(0.025)	(0.026)	(0.025)	(0.024)	(0.026)
Skill requirements, reference: w/o qualification							
Vocational training				0.754**			0.786*
				(0.091)			(0.113)
University degree				0.863			0.969
				(0.154)			(0.192)
Employee shares by skill level, reference: share of unskilled workers							
Share of skilled workers with vocational training					0.935		1.076
					(0.183)		(0.232)
Share of skilled workers with university degree					0.892		1.031
					(0.293)		(0.369)
Additional skill requirements							
Leadership ability						1.041	1.041
						(0.201)	(0.201)
Experience						0.919	0.948
						(0.070)	(0.075)
Further skills from training outside formal qualification						0.791***	0.800**
						(0.069)	(0.071)
Foreign lang.						0.853	0.841
						(0.184)	(0.162)
Social skills						0.956	0.970
						(0.104)	(0.110)
Observations	2,982	2,982	2,982	2,904	2,982	2,982	2,904
Pseudo R-squared	0.0254	0.0644	0.0675	0.0695	0.0675	0.0700	0.0714

Federal states cluster robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: Coefficients are reported as odds ratios, where the null effect is 1. All specifications include year dummies, dummies for the federal states where the firms are located, industrial sectors, and a dummy that indicates firms reporting both the last case of a successful and an unsuccessful recruitment case. Firms size class based on all employees, regardless whether employees are subject to social security contributions or not. Firms are considered that used both referrals and formal ways as search channels ($s_i = 1, 1 \leq a_i \leq 6$). Sample is further restricted to cases with recruitment of former unemployed.
Source: IAB Job Vacancy Survey 2012-2016. Own computations.

Table 22: Detailed empirical results of table 12: Number of applicants per vacancy and search duration as dependent variable

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Neg. Bin. II	Neg. Bin. II	Neg. Bin. II	Neg. Bin. II	Neg. Bin. II	Neg. Bin. II	Neg. Bin. II	Neg. Bin. II
Number of employees (4 firm size classes, reference: 1 ≤ ee < 10)								
10 ≤ ee < 50	0.321***		0.271***	0.272***	0.286***	0.292***	0.238**	0.219**
	(0.085)		(0.083)	(0.084)	(0.077)	(0.079)	(0.098)	(0.096)
50 ≤ ee < 250	0.656***		0.547***	0.550***	0.540***	0.561***	0.608***	0.578***
	(0.104)		(0.100)	(0.100)	(0.095)	(0.096)	(0.130)	(0.129)
250 ≤ ee	0.980***		0.836***	0.861***	0.814***	0.874***	1.049***	1.038***
	(0.096)		(0.089)	(0.093)	(0.088)	(0.088)	(0.118)	(0.116)
Formal search index		0.190***	0.142***	0.152***	0.141***	0.151***	0.095***	0.102***
		(0.015)	(0.012)	(0.012)	(0.012)	(0.011)	(0.016)	(0.016)
Skill requirements, reference: w/o qualification								
Vocational training				-0.332***		-0.306***	-0.450***	-0.417***
				(0.070)		(0.071)	(0.110)	(0.120)
University degree				-0.376***		-0.483***	-0.693***	-0.639***
				(0.077)		(0.089)	(0.131)	(0.155)
Employee shares by skill level, reference: share of unskilled workers								
Share of skilled workers with					-0.522***	-0.340**	-0.272*	-0.261*
vocational training					(0.139)	(0.133)	(0.142)	(0.144)
Share of skilled workers with					0.035	0.379***	0.530***	0.475**
university degree					(0.096)	(0.123)	(0.200)	(0.205)
Additional skill requirements								
Leadership ability								-0.423***
								(0.091)
Experience								0.041
								(0.095)
Further skills from training								-0.363***
outside formal qualification								(0.086)
Foreign lang.								0.176*
								(0.103)
Social skills								0.106
								(0.079)
α	0.915***	0.928***	0.897***	0.898***	0.890***	0.889***	1.011***	0.995***
	(0.085)	(0.087)	(0.081)	(0.081)	(0.081)	(0.081)	(0.132)	(0.129)
Number of observations	28,735	28,735	28,735	28,270	28,733	28,269	8,341	8,341
Pseudo R-squared	0.0601	0.0561	0.0646	0.0667	0.0671	0.0694	0.0953	0.100
Log likelihood	-23,247	-23,347	-23,137	-22,779	-23,075	-22,711	-6,501	-6,469

Federal states cluster robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: Coefficients are reported as semi-elasticities, a one-unit change in x_i changes the conditional mean, μ_i, by the multiplier $1+\beta_i$. All specifications include year dummies, dummies for the federal states where the firms are located, industrial sectors, and a dummy that indicates firms reporting both the last case of a successful and an unsuccessful recruitment case. Results in columns (7) and (8) are from specifications that are based on a restricted sample of firms that report successful recruitment and used both formal channels und referrals.
Source: IAB Job Vacancy Survey 2012-2016. Own computations.

Table 23: Detailed empirical results of table 14: Ordinal least square regression for the additional recruiting costs in Euro

	(1)	(2)	(3)
	Based on a sample of firms that report only successful recruitment cases and that used		
	either referrals or both referrals and formal strategies	only formal strategies	either referrals or formal strategies or both
	$(s_i = 1, 0 \leq a_i \leq 6)$	$(s_i = 0, 1 \leq a_i \leq 6)$	$(s_i \geq 0, 0 \leq a_i \leq 6)$
	(1)	(2)	(3)
	OLS	OLS	OLS
Usage of referrals			-494.924***
			(81.853)
Number of employees (4 firm size classes, reference: 1 ≤ ee < 10)			
10 ≤ ee < 50	90.011*	242.786**	161.619***
	(48.821)	(83.750)	(44.721)
50 ≤ ee < 250	330.610***	558.925***	428.605***
	(68.986)	(109.851)	(79.324)
250 ≤ ee	913.514***	1,072.534***	1,015.058***
	(151.814)	(185.320)	(165.253)
Skill requirements, reference: w/o qualification			
Vocational training	42.110	67.316	24.578
	(35.560)	(78.876)	(34.542)
University degree	794.600***	1,629.735***	1,288.711***
	(179.518)	(161.156)	(161.305)
Employee shares by skill level, reference: share of unskilled workers			
Share of skilled workers with	327.216***	633.352***	402.707***
vocational training	(100.597)	(195.770)	(117.443)
Share of skilled workers with	-48.841	619.943	51.937
university degree	(209.777)	(419.909)	(227.017)
Additional skill requirements			
Leadership ability	556.775**	2,262.960***	1,392.226***
	(237.467)	(385.705)	(239.126)
Experience	119.714	561.201***	330.464***
	(75.368)	(100.284)	(52.114)
Further skills from training outside formal qualification	103.914	-144.368	-18.372
	(62.068)	(149.503)	(79.577)
Foreign lang.	171.637	1,082.673***	630.261***
	(123.368)	(256.266)	(138.836)
Social skills	42.605	-2.209	40.619
	(84.500)	(133.845)	(97.682)
Constant	-519.513***	-968.304***	-362.268***
	(119.756)	(250.347)	(120.371)
Observations	6,265	5,746	12,011
R-squared	0.075	0.154	0.123

Federal states cluster robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: The specification and the sample restriction for column (1) refer to the specification and the sample restriction in column (6) of table 5. The specification and the sample restriction for column (2) refer to the specification and the sample restriction in column (6) of table 6. The specification and the sample restriction for column (3) refer to the specification and the sample restriction in column (7) of table of table 7. All specifications include year dummies, dummies for the federal states where the firms are located, industrial sectors, and a dummy that indicates firms reporting both the last case of a successful and an unsuccessful recruitment case. Firms size class based on all employees, regardless whether employees are subject to social security contributions or not.
Source: IAB Job Vacancy Survey 2012-2016. Own computations.

Table 24: Detailed empirical results of columns (1)–(4) of table 15: Probability to recruit with referrals as dependent variable (y_i^S)

	(1) logit	(2) logit	(3) logit	(4) logit
Number of employees (4 firm size classes, reference: 1 ≤ ee < 10)				
10 ≤ ee < 50	0.791**	0.836*	0.649*	0.697
	(0.0837)	(0.0906)	(0.149)	(0.155)
50 ≤ ee < 250	0.590***	0.681***	0.689	0.824
	(0.0842)	(0.0999)	(0.173)	(0.215)
250 ≤ ee	0.371***	0.452***	0.385**	0.444*
	(0.0848)	(0.107)	(0.160)	(0.196)
Recruitment effort (Additional costs in 1000 Euros)	0.901***	0.963**	0.824	0.910
	(0.0263)	(0.0178)	(0.131)	(0.0874)
Formal search index		0.665***		0.713***
		(0.0192)		(0.0455)
Skill requirements, reference: w/o qualification				
Vocational training	0.900	0.954	0.854	0.872
	(0.0986)	(0.120)	(0.164)	(0.181)
University degree	0.829	0.859	0.898	0.885
	(0.116)	(0.136)	(0.431)	(0.436)
Employee shares by skill level, reference: share of unskilled workers				
Share of skilled workers with vocational training	1.444**	1.333	1.805*	1.727*
	(0.246)	(0.259)	(0.574)	(0.566)
Share of skilled workers with university degree	1.333	1.260	3.474*	3.191*
	(0.307)	(0.314)	(2.445)	(2.093)
Additional skill requirements				
Leadership ability	1.382***	1.371***	0.633	0.670
	(0.138)	(0.135)	(0.233)	(0.242)
Experience	1.073	1.074	1.440	1.408
	(0.0931)	(0.0954)	(0.343)	(0.317)
Further skills from training outside formal qualification	1.141	1.211**	0.609**	0.678**
	(0.105)	(0.116)	(0.119)	(0.122)
Foreign lang.	0.803*	0.773*	0.413***	0.430**
	(0.0965)	(0.107)	(0.136)	(0.159)
Social skills	0.743***	0.772***	1.030	1.086
	(0.0715)	(0.0764)	(0.199)	(0.243)
Former employment status, reference: out of labor force				
unemployed	0.611***	0.624***		
	(0.0762)	(0.0865)		
employed	0.943	0.980		
	(0.0763)	(0.0875)		
Constant	2.349***	4.238***	2.353*	4.142***
	(0.658)	(1.383)	(1.042)	(2.001)
Observations	4,077	4,077	1,030	1,030
Pseudo R-squared	0.0381	0.0713	0.0681	0.0883

Federal states cluster robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: Coefficients are reported as odds ratios, where the null effect is 1. All specifications include year dummies, dummies for the federal states where the firms are located, industrial sectors, and a dummy that indicates firms reporting both the last case of a successful and an unsuccessful recruitment case. Firms size class based on all employees, regardless whether employees are subject to social security contributions or not. Firms are considered that used both referrals and formal ways as search channels ($s_i = 1, 1 \leq a_i \leq 6$). Sample is restricted to successful recruitment cases. Estimation results of the specification in columns (3) and (4) are based on a sample that is further restricted to cases with recruitment of former unemployed.
Source: IAB Job Vacancy Survey 2014 and 2015

Table 25: Detailed empirical results of columns (5)–(8) of table 15: Number of applicants per vacancy and search duration as dependent variable, NB II model

	(5)	(6)	(7)	(8)
	Neg. Bin. II	Neg. Bin. II	Neg. Bin. II	Neg. Bin. II
Number of employees (4 firm size classes, reference: $1 \le ee < 10$)				
$10 \le$ ee < 50	1.478***	1.373***	0.209	0.150
	(0.175)	(0.160)	(0.129)	(0.137)
$50 \le$ ee < 250	1.908***	1.653***	0.618***	0.521***
	(0.248)	(0.226)	(0.162)	(0.169)
$250 \le$ ee	3.238***	2.632***	1.281***	1.114***
	(0.330)	(0.330)	(0.156)	(0.154)
Recruitment effort (Additional costs in 1000 Euros)	1.020	1.006	0.027	0.011
	(0.013)	(0.013)	(0.017)	(0.018)
Formal search index		1.231***		0.179***
		(0.030)		(0.026)
Skill requirements, reference: w/o qualification				
Vocational training	0.773***	0.719***	-0.519***	-0.562***
	(0.076)	(0.071)	(0.151)	(0.153)
University degree	0.611***	0.574***	-0.971***	-0.992***
	(0.060)	(0.057)	(0.204)	(0.207)
Employee shares by skill level, reference: share of unskilled workers				
Share of skilled workers with vocational training	0.723	0.723	-0.519*	-0.525*
	(0.169)	(0.161)	(0.282)	(0.278)
Share of skilled workers with university degree	1.140	1.142	0.062	0.056
	(0.281)	(0.270)	(0.209)	(0.202)
Additional skill requirements				
Leadership ability			-0.111	-0.115
			(0.136)	(0.145)
Experience			-0.053	-0.049
			(0.104)	(0.109)
Further skills from training outside formal qualification			-0.345***	-0.362***
			(0.073)	(0.073)
Foreign lang.			0.266	0.255
			(0.174)	(0.169)
Social skills			0.079	0.054
			(0.111)	(0.109)
α	1.017***	0.978***	1.176***	1.147***
	(0.109)	(0.108)	(0.151)	(0.150)
Number of observations	8216	8216	2940	2940
Pseudo R-squared	0.0608	0.0702	0.107	0.112
Log likelihood	-7569	-7493	-2495	-2480

Federal states cluster robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: Coefficients are reported as semi-elasticities, a one-unit change in x_i changes the conditional mean, μ_i, by the multiplier $1+\beta_i$. All specifications include year dummies, dummies for the federal states where the firms are located, industrial sectors, and a dummy that indicates firms reporting both the last case of a successful and an unsuccessful recruitment case. Sample is restricted to successful recruitment cases.
Source: IAB Job Vacancy Survey 2014 and 2015

Appendix VII: Alternative specification for the model based on the Negative Binomial II distribution that explains the number of applicants per vacancy and search duration (see section 4).

Another negative binomial distribution is the so called negative binomial I with the expectation and variance given by (Cameron/Trivedi, 2005: p. 676):

$$E[y|\mu,\delta] = \mu \qquad Var[y|\mu,\delta] = (1+\delta)\mu \tag{15}$$

The variance, $Var[.]$, exceeds the mean in case of $\delta > 0$ and $\mu > 0$. We use this alternative specification for a further robustness check; again we define:

$$\mu_i \equiv y_i = \exp(b_0 + \mathbf{b_1 x_i}) \tag{16}$$

The maximum likelihood to estimate parameters $b_0, \mathbf{b_1}$ and the additional parameter δ is then:

$$\ell_i(b_0,\mathbf{b_1},\delta) = \delta^{-1}\exp(b_0+\mathbf{b_1 x_i})\log\left[\frac{\delta^{-1}}{\delta^{-1}+1}\right]+y_i\log\left[\frac{1}{\delta^{-1}+1}\right]+\log\left\{\left(\frac{\Gamma[y_i+\delta^{-1}\exp(b_0+\mathbf{b_1 x_i})]}{\Gamma[\delta^{-1}\exp(b_0+\mathbf{b_1 x_i})]\Gamma(y_i+1)}\right\}\tag{17}$$

Table 26 presents the results. Parameter δ is significantly positive as we expected, indicating overdispersion. The point estimates of the coefficients for the firm size classes are slightly smaller than the point estimates based on the negative binomial II model, but the differences are not significant (see table 12). Thus, these results corroborate our findings regarding hypothesis H6 in section 4.

Table 26: Robustness checks: Number of applicants per vacancy and search duration as dependent variable, NB I model

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Neg. Bin. I	Neg. Bin. I	Neg. Bin. I	Neg. Bin. I	Neg. Bin. I	Neg. Bin. I	Neg. Bin. I	Neg. Bin. I
Number of employees (4 firm size classes, reference: $1 \leq ee < 10$)								
$10 \leq ee < 50$	0.219***		0.186***	0.188***	0.194***	0.202***	0.120***	0.115***
	(0.028)		(0.027)	(0.026)	(0.028)	(0.026)	(0.030)	(0.032)
$50 \leq ee < 250$	0.454***		0.380***	0.389***	0.379***	0.399***	0.333***	0.326***
	(0.028)		(0.028)	(0.029)	(0.029)	(0.029)	(0.039)	(0.040)
$250 \leq ee$	0.713***		0.603***	0.629***	0.592***	0.642***	0.664***	0.653***
	(0.035)		(0.036)	(0.035)	(0.036)	(0.034)	(0.049)	(0.051)
Formal search index		0.139***	0.107***	0.114***	0.107***	0.115***	0.080***	0.083***
		(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.015)	(0.014)
Skill requirements, reference: w/o qualification								
Vocational training				-0.161***		-0.166***	-0.216***	-0.211***
				(0.036)		(0.038)	(0.048)	(0.055)
University degree				-0.223***		-0.324***	-0.372***	-0.367***
				(0.046)		(0.050)	(0.070)	(0.084)
Employee shares by skill level, reference: share of unskilled workers								
Share of skilled workers with					-0.176***	-0.088*	-0.215***	-0.213***
vocational training					(0.058)	(0.053)	(0.077)	(0.077)
Share of skilled workers with					0.184***	0.410***	0.320***	0.269**
university degree					(0.071)	(0.077)	(0.117)	(0.119)
Additional skill requirements								
Leadership ability								-0.214***
								(0.045)
Experience								0.018
								(0.037)
Further skills from training								-0.154***
outside formal qualification								(0.036)
Foreign lang.								0.132***
								(0.049)
Social skills								0.113***
								(0.026)
δ	0.414***	0.419***	0.408***	0.412***	0.405***	0.408***	0.518***	0.514***
	(0.072)	(0.073)	(0.071)	(0.072)	(0.071)	(0.072)	(0.147)	(0.147)
Number of observations	28,735	28,735	28,735	28,270	28,733	28,269	8,341	8,341
Pseudo R-squared	0.0306	0.0285	0.0342	0.0350	0.0352	0.0366	0.0298	0.0317
Log likelihood	-23,977	-24,029	-23,889	-23,552	-23,862	-23,512	-6,971	-6,957

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: Coefficients are reported as semi-elasticities, a one-unit change in x_i changes the conditional mean, μ_i, by the multiplier $1+\beta_i$. All specifications include year dummies, dummies for the federal states where the firms are located, industrial sectors, and a dummy that indicates firms reporting both the last case of a successful and an unsuccessful recruitment case. The skill requirements comprise three levels: w/o qualification (reference group), vocational training, or university degree. The employee shares by skill level comprise three groups: unskilled workers (reference group), skilled workers with vocational training, skilled workers with university degree. The additional skill requirements are a set of dummy variables that denote whether the vacancy requires leadership ability, experience, further skills from training outside formal qualification, foreign languages, and/or social skills. Results in columns (7) and (8) are from a specification that are based on a restricted sample of firms that report successful recruitment and used both formal channels und referrals.
Source: IAB Job Vacancy Survey 2012-2016. Own computations.

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Imprint

IAB-Discussion Paper 33/2017
4 December 2017

Editorial address
Institute for Employment Research
of the Federal Employment Agency
Regensburger Straße 104
D-90478 Nuremberg

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Technical completion
Renate Martin

Website
http://www.iab.de

Download of this Discussion Paper
http://doku.iab.de/discussionpapers/2017/dp3317.pdf

ISSN 2195-2663

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