Understanding the Role of the Public Employment Agency*

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Abstract

The Public Employment Agency (PEA) provides intermediation services in the labor market. We investigate the implications of having such an additional market place using a tractable search model, and explain why only a fraction of firms use the PEA as search channel despite its free service. We highlight the registering firms' tradeoff between the negative selection of applicants and the lower wages possible at the PEA. Our theory also explains which job-types are more likely to be registered. We test these theoretical predictions empirically using the German Job Vacancy Survey and the German Socio-Economic Panel and find strong support for them.

Keywords: Intermediation, Public Employment Agency, Labor Search

JEL: J6

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1 Introduction

In most industrialized countries Public Employment Agencies (hereafter, PEA) provide job-broking services – help job seekers to obtain jobs and employers to fill vacancies, enforce search requirements attached to unemployment benefit receipt, and train unemployed workers to improve their employability. While the latter two responsibilities have received much attention in the economics literature,[1] very little is known about the intermediation services provided by the PEA and their effect on the labor market. The market places provided by PEAs are open to all job seekers and vacancies at zero cost. The existing empirical literature shows that up to 85 percent of non-employed job seekers and 48 percent of vacancies use the PEA as search channel.[2] Using a theoretical model, we obtain novel implications regarding the application/search behaviors of workers and market outcomes, e.g. the wage and the factors influencing the decision to use a certain search channel. These and other implications are tested empirically. The results strongly support our theory.

Our approach takes seriously the role of the PEA to serve as a coordination mechanism in the job seekers' application process. The PEA does much more than just providing an additional platform or market place. The staff at the PEA observes and guides the application behavior of unemployed job seekers and directs it towards vacancies.[3] It whereby helps to spread applications more evenly among all registered vacancies. This process requires the centralization and coordination that only intermediaries are able to pursue. Whatever new technologies firms develop and whatever efforts they make for strengthening their own recruiting team, individual firms are not able to coordinate the application behavior of job seekers. The same is true for workers.

In the theory part, we investigate the implication of having a PEA in the labor market, which provides a market place with less (or no) coordination frictions. We do so by constructing a simple equilibrium model where firms decide whether to compete in wages, which allows them to attract applicants in the private market, or to offer only the reservation wage and rely on the intermediation services provided by the PEA to receive applications.[4] In our setup, all unemployed are registered at

[1] Early studies on the effects of unemployment benefits and unemployment duration are Narendaranathan et al. (1985), Katz and Meyer (1990), Hunt (1995), and Nickell and Layard (1999). More recent studies are Lalive and Zweimüller (2004), Lalive (2007), and Lalive et al. (2015). The effect of sanctions is among others studied by Van den Berg et al. (2004), Abbring et al. (2005), Lalive et al. (2005), and Svarer (2011). Couch (1992), Heckman et al. (1999), Lechner and Wunsch (2009), and Lechner et al. (2011) study the effects of training programs.

[2] See Holzer (1988) and Blau and Robins (1990) for the US, Osberg (1993) for Canada, Gregg and Wadsworth (1996) for the UK, Addison and Portugal (2002) for Portugal, and Weber and Mahringer (2002) for Austria. The evidence on the fraction of registered vacancies is scarce. Pollard et al. (2012) report in a survey for the Department of Work and Pensions that in the Unitied Kingdom 39 percent of all establishments used the Jobcentre Plus in 2011. We find that in the years 2005 to 2008 around 48.3% of all vacancies in Germany registered with the PEA.

[3] More than half of the 90,000 PEA's employees work in the intermediation to help workers and vacancies to find a good match. The German government spends in 2012 0.3% of GDP (8.9 billion EUR) on the administration of the PEA. The corresponding figures are 0.04% (6 billion USD) in USA and 0.05% (250 billion JPY) in Japan.

[4] A directed search framework (instead of a random search framework) best fits with this purpose. Some major implications of our model cannot be obtained from random search models. In addition, the following empirical observations support directed search approaches. Van Ours and Ridder (1992) show that firms with vacancies typically collect a pool of applicants before deciding on whom to hire and Wolthoff (2016) shows that for a given vacancy, almost 5 interviews are conducted. Gautier, Moraga-Gonzalez and Wolthoff (2016) and Belot, Kircher, and Muller (2016) give evidence that unemployed workers apply simultaneously to multiple jobs. For evidence on German data we refer the reader to the empirical section 4.1.

the PEA. For them, searching in the private (or decentralized) market is costly. The intermediation services provided by the PEA ensure a positive matching probability for firms. This reduces the necessity to compete for applications via wages and allows firms to pay lower wages compared to the decentralized market. In contrast, the decentralized mechanism of a directed search market requires that vacancies offer a high wage to attract workers. Given these different allocation mechanisms, job seekers are not willing to engage in costly search for a better-paid job in the private market unless the prospect to be successful is good enough. This gives rise to positive self-selection of workers into the private market. The trade-off between lower coordination frictions and lower wages in the PEA on the one side with a negative selection of workers on the other side explains why not all vacancies (within one job category) are registered with the PEA.

We empirically test of our theory. Using vacancy data from Germany, we show – using within vacancy variation – that the fraction of suitable applicants coming via the PEA is about 5.7 to 12.5 percent lower than the fraction of suitable applicants coming via the private market.[5] This result is very robust, since our data set allows us to control for vacancy fixed effects. We also investigate whether firms registered with the PEA are offering lower wages by looking at three pieces of information. First, using the German Job Vacancy Survey we find a PEA wage gap between unregistered and registered firms of 2.9 to 5.4 percentage points. Second, firms registered with the PEA are more likely to report difficulties in the recruitment process, because their applicants demanded higher wages. This not only supports the direct evidence that registered vacancies offer lower wages than unregistered vacancies, but also implies that one and the same worker can be offered different wages, something which is predicted by our theory. The wage difference and the difference in the higher fraction of refused job offers because applicants demanded higher wages persist after controlling for many observable worker-, firm-, and job-characteristics. Most importantly our control variables allow us to rule out alternative explanations for the observed PEA wage gap. By controlling for firm size as well as indicator variables concerning "low sales", "financial constraints", and "skilled labor shortage" we are able to control – along these dimensions – for a selection of less productive firms into registering with the PEA. By controlling for worker characteristics like age, gender, experience, and most importantly the previous employment status, we are able to control for a selection of less productive workers into unemployment and for the enforcement policy of the PEA, which requires unemployed workers to accept jobs with lower wage offers. Our third piece of evidence is based on individual level data from the German Socio-Economic Panel (GSEOP). Here we can control for worker fixed effects and find a PEA wage gap of 3.0 percentage points, if the PEA was actively involved in forming the match.

Our theoretical analysis suggests that the implicit cost associated with the less suited pool of applicants coming via the PEA explains why not all vacancies register with the PEA. We test this

[5]This evidence is complementary to the evidence provided in the existing literature, which shows that less suited workers are more likely to use the PEA. Our complement is important to understand the role of the PEA in the labor market, since the evidence from the workers' side alone does not necessarily imply that registered vacancies receive on average a less suited pool of applicants. It could have been that the PEA has an informational advantage and sorts out less suited workers and thereby helps registered firms to overcome information asymmetries. Instead, our empirical result suggests that this is not the case.

hypothesis by looking at the variation in PEA registration rates across occupations.[6] In our theory we use two measures to characterize the suitability of a pool of applicants. The first one is the overall fraction of certainly productive workers, i.e., the share of job seekers, who are always suitable. The second one is the probability that an uncertain worker is suitable. We structurally estimate these two measures using the observed fractions of suitable applicants coming via the private market and via the PEA respectively. Our empirical analysis shows that these two measures are, as suggested by our theory, highly positively correlated with the use of the PEA as search channel. They explain together 18.3% in the overall variation in occupation specific PEA registration rates.[7] This strongly supports our theoretical predictions on the factors, which determine the use of the PEA as search channel.

Our theory also predicts that vacancies associated with high job creation costs or high interview costs are less likely to be registered with the PEA. The intuition is that the high flexibility of wages and matching probabilities in the private market ensures that firms are able to pass on part of these costs to workers. This is not possible in the PEA, since wages stay at workers' reservation wages and the allocation technology remains constant. One might expect that jobs requiring a high qualification or permanent jobs are associated with high interview and/or job creation costs in comparison. In this way, our theory can also explain why we find empirically that jobs requiring a high qualification or permanent jobs are less likely to be registered with the PEA.

While our data is only available for the period after the Hartz reforms, our results help to understand the importance of the Hartz III reform, which restructured the intermediation service of the Public Employment Agency, as part of the Hartz reform package. A growing macroeconomic literature (see for example, Krause and Uhlig, 2012; Krebs and Scheffel, 2013; Launov and Wälde, 2016; Felbermayr et al., 2016; and Bradley and Kugler, 2017) has investigated the contribution of the different parts of the Hartz reform package using structural models. Our results show that an increased matching efficiency at the PEA is associated with lower wages on average, i.e., does *not* lead to higher wages as the structural matching models used in this literature suggest.

The sequel of the paper is organized as follows. This introductory section closes with the literature survey. Section 2 describes how the PEA works in Germany. Section 3 presents the theoretical model of the labor market in the presence of the PEA. Section 4 investigates the empirical implications of the theory. Section 5 concludes. All proofs and some omitted tables are collected in the Appendix.

Related Literature The existing literature studies the use of the PEA and the effects of using the PEA only from the job seekers' perspective. It shows that unemployment benefit recipients, low skilled workers, long-term unemployed and workers with few job opportunities are more likely to use

[6] In the German Job Vacancy Survey (2005 to 2008) we find that the PEA registration rates of vacancies for corporate managers (20.5%), business (29.4%) and legal (33.8%) professionals, or medical doctors (30.2%), are far below average (48.3%) while the PEA registration rates of gardeners (68.2%), bricklayers (75.4%), electricians (62.2%), painters (75.7%), and bus (73.1%) and taxi (59.9%) drivers are far above average. Vacancies for economists are registered with the PEA in 21.3% of all cases.

[7] Adding these two measures to a long list of job and firm characteristics increases the R in an occupation-level OLS regression explaining the occupation specific PEA registration rates from 15.5% to 33.8%.

a PEA.[8] The empirical evidence for the effect on wages is mixed. Holzer (1988) reports for the US and Addison and Protugal (2002) for Portugal that workers, who searched through the PEA, received lower wage offers (after controlling for worker characteristics). Osberg (1993) finds for Canada and Weber and Mahringer (2002) for Austria that the wage difference disappears after controlling for worker characteristics. Our result suggests that wages paid by registered vacancies in Germany are lower than the wages paid by unregistered vacancies. If worker-, firm-, and job- characteristics are not sufficient to account for the gap, then our analysis suggests, that the coordination mechanism in the PEA could be responsible for why studies using individual level data (like our study as well) obtain a wage gap even after controlling for observable characteristics.

In a companion paper Holzner and Watanabe (2018) use the German Job Vacancy Survey to show that the PEA decreases coordination frictions, i.e., distributes the applications of its job seekers more evenly than the private market. This result holds not only for total applications but also for applications, which firms regard as suitable. Using within vacancy variation, they are able to control for observed and unobserved vacancy characteristics, and whether the results are driven by reverse causality or measurement error. They also document that the use of the PEA as search channel and the number of suitable applicants mediated by the PEA are associated with a reduced search duration for vacancies.

The pioneering theoretical work of the PEA is developed by Pissarides (1979). We adopt the baseline setups in accordance with his model as much as possible. Like him we assume that all unemployed are registered at the PEA, that searching in the decentralized market is costly for workers, and that firms can choose between two alternative methods of finding a worker: the search market and the PEA. There are two major differences between his and our model. First, workers are homogeneous in Pissarides (1979), while the key ingredient of our model is that workers differ in expected suitability for the job. Second, Pissarides (1979) considers a random search model and assumes an exogenous and identical wage in both markets. In contrast, we show that firms in the decentralized market choose to post higher wages than firms registered with the PEA using a directed search model.[9] Since the value of searching in the private market is higher for workers with a high expected suitability, the endogenous wage differential allows firms in the private market to attract a better pool of applicants. In an extension, Pissarides (1979) considers the limiting case where search frictions are eliminated in the PEA. He finds that in this case the private market collapses and all workers search via the PEA. This is in contrast to our model. We show that the positive selection of workers in the search market ensures the existence of the decentralized search market even if the PEA manages to match the short

[8]See Holzer (1988) and Blau and Robins (1990) for the US, Osberg (1993) for Canada and Gregg and Wadsworth (1996) for the UK.

[9]In the directed search literature, where workers simultaneously apply for multiple jobs, Albrecht, Gautier and Vroman (2006) show that firms engage in Bertrand competition, if their applicant receives two or more offers. Unlike in their setup, we assume wage commitment and show that a low wage can survive in equilibrium due to the coordinated allocation mechanism used by the PEA. Galenianos and Kircher (2009) consider the case of commitment with homogeneous workers and show the existence of an equilibrium wage dispersion. In our model, there are some workers, who use both the search market and the PEA and might therefore receive multiple offers – one from the search market and the other from the PEA. In this setup we show that, while the search market has a unique wage, a wage differential exists between the search market and the PEA. Our modeling choice reflects the institutional difference between the two market places in reality.

side of the market.

Our model is also related to the literature of intermediation. Watanabe (2010) provides a model of middlemen (e.g., retailers, wholesalers, trading entrepreneurs, dealers or brokers of services and durable goods and assets),[10] where he demonstrates that backed by the capability of dealing with many agents at a time, middlemen find it optimal to provide customers with proximity or a lower likelihood of experiencing stockout, and to charge a higher price. That the PEA in the present framework provides a coordinated transaction is similar to his middlemen's capability of pursuing large-scaled dealings. Our approach well captures the intermediary's role to mitigate coordination frictions. In contrast to the literature, however, the PEA does not act as a private agent, who charges a premium for their service. This raises the question why not all agents use the middlemen. The answer given in this paper is that firms have to trade off the lower wage and the lower degree of coordination frictions with the disadvantage of facing a less suited pool of applicants in the PEA. In a recent progress, Gautier, Hu and Watanabe (2016) offer a hybrid model of middlemen and market-makers (i.e., platform), and study the choice of the two alternative intermediation modes. Unlike in the present model, agents are homogeneous and the issue of differential composition of heterogeneous agents is not addressed.

There are very few other papers that consider the role of the PEA.[11] Belot et al. (2016) use a field experiment to show that providing tailored advice on alternative occupations to unemployed job seekers on the internet broadens the set of jobs they consider and increases their job interviews. Fougère et al. (2009) uses a structural partial search equilibrium model to investigate the hypothesis by Pissarides (1979) that a more efficient PEA crowds out private search effort. They consider exogenous, search-channel-specific wage-offer distributions and allow for an endogenous search intensity of workers. Using French data to structurally estimate the model they find that the exit rate from unemployment increases with the arrival rate of job contacts obtained by the PEA. This is especially the case for low-skilled workers. Krause and Uhlig (2012) and Launov and Wälde (2014) use a structural model to analyze to which extent a reduction of unemployment benefits on the one hand and short-time work subsidies provided by the PEA or an increase in operating efficiency of the PEA on the other are responsible for the decline in unemployment in Germany from 11.7% in 2005 to 7.8% in 2008.

[10] The seminal work in the literature of middlemen is Rubinstein and Wolinsky (1987). While most of the models in the literature would be viewed as describing general markets, there are some models (e.g., Yavas, 1994; Masters, 2007; Watanabe, 2010) that feature labor market intermediation or turnover behaviors. See Watanabe (2018ab) for the references of the recent contributions.

[11] Casella and Hanaki (2008) and Galenianos (2013) study firms' use of referrals by their own employees in addition to formal hiring channels. Referred workers may be more suited for the job, because referred workers carry a more accurate productivity signal than workers contacted through a formal search channel. The search channels in our model do not differ in their signaling ability. They differ in the allocation mechanism used. In the search market firms can increase the probability to meet a worker by offering a higher wage, while firms' meeting probability at the PEA is independent of the wages they offer. The novelty of our paper is to show that the higher degree of wage competition among firms in the search market compared to the PEA leads to a positive selection of applicants.

2 The Public Employment Agency

To motivate the setup of the PEA in our theoretical analysis we start with describing how the PEA works. In 2015 the PEA in Germany had an overall budget of 31.5 Billion Euros. Around one fourth of the total budget, i.e., 7.93 Billion Euros, was spent on administration including the wage costs for the roughly 90,000 workers employed at the PEA. The German government therefore spends around 0.3% of German GDP on the administration cost of the PEA. A significant fraction of employees deal with the administration of unemployment benefits. Still, more than half of the PEA's employees work in the intermediation to help workers and vacancies to find a good match. In this section we explain, what kind of intermediation services are provided by the PEA (compare Figure 1).

The PEA provides an online search platform (https://jobboerse.arbeitsagentur.de), where job seekers can upload their curriculum vitae, post job wanted adds, and search actively for vacancies posted. Equivalently, firms can post their vacancies and search actively for registered workers. All unemployed workers, who receive benefits, are required to register. For vacancies registration is voluntary.

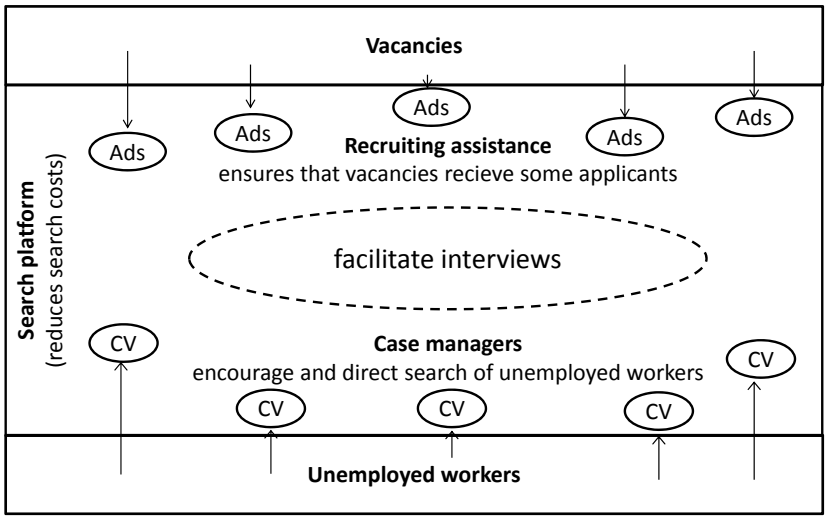

Figure 1: Services provided by the PEA

If a worker becomes unemployed, she registers with the PEA and is assigned to a case manager. The case manager will interview the person. A worker, who has some deficits, will be offered training. The majority of unemployed do not get training, they are only taught how to use the platform.[12] The case manager will propose certain jobs to the worker. With their experience case managers can encourage search, broaden the view of applicants, and suggest jobs, which workers would not have considered on their own.

On top of coaching unemployed workers, the PEA offers recruiting assistance to vacancies. Firms which post a vacancy on the platform can decide whether to make the vacancy available for recommendations by case managers. They can also ask their contact person at the PEA to propose workers.

[12] In 2013 around 5% of all registered unemployed in Germany received training (Bundesagentur für Arbeit, 2013).

The contact person is asked to recommend at least one worker within 48 hour. In case the vacancy asks for recruiting assistance the contact person can view the platform account of the specific vacancy and manage the number of recommendations made by case managers accordingly. This type of recruiting assistance does not only lower recruitment costs, but also enables firms to minimize the risk of not receiving any applicant.

To summarize, the platform offered by the PEA reduces search costs for job seekers and vacancies. More importantly, its intermediation services reduce coordination frictions, i.e., the friction that some vacancies might receive many applications while others receive none. The fact that the staff at the PEA can guide the application behavior of their unemployed job seekers and direct it towards vacancies helps to spread applications more evenly among all registered vacancies. We will therefore assume in the theory part that the PEA reduces coordination frictions for registered firms. This assumption is also empirically backed by the findings of Holzner and Watanabe (2018).

3 Theoretical Analysis

In this theory section we analyze the implications of having a PEA in the labor market, which provides a market place with less (or no) coordination frictions in the job application stage. We do so by building a simple equilibrium model where firms decide whether they offer a competitive wage, which makes the vacancy attractive in the private market, or to offer the reservation wage and rely on the intermediation services of the PEA for applicants. We first present the baseline model and show under which conditions firms register their vacancy with the PEA. This explains the variation in PEA registration across identical vacancies. Our theory also offers predictions about wages and the fraction of suitable applicants, which we will test empirically in section 4. We then analyze to which degree our model is able to explain the differences in registration rates across occupations.

3.1 Setup

We consider an economy with a mass of unemployed workers and firms. We denote by $v \in (0, \infty)$ the population ratio of firms to unemployed workers. Each firm has one job vacancy that needs to be filled, and each worker wishes to find a job. The matching process is shaped by coordination and information frictions.

There are two types of workers. A fraction m of them is certain that they fulfill the qualification requirement. They will always produce an output, normalized to unity, at any job, which requires this level of qualification. The remaining workers are uncertain of whether they fulfill the qualification requirement. They are only productive with probability $\delta \in (0, 1)$. So, with probability $1 - \delta$, a match between an uncertain worker and a firm produces 0. If an uncertain worker fulfills the qualification requirement, he is as productive as a certain worker. Thus, all certain workers and the fraction δ of uncertain workers are referred to as suitable or productive workers. While the information about whether or not a worker is productive for a job is revealed at the stage of the job interview, the worker's type (certain or uncertain) is private knowledge. The two dimensions

m - the overall fraction of certainly productive workers - and δ - the probability that an uncertain worker is productive - determine average productivity and information frictions. This setup allows us to combine uncertainty about match quality with private information about the qualification level on the workers' side. Differences across these two measures of "applicant suitability" are empirically highly relevant in explaining the differences in PEA registration rates across occupations as shown in section 4.4.

There are two markets (or two channels) through which matching between firms and unemployed workers can occur (see Figure 2). One market is provided by the Public Employment Agency (PEA), where all unemployed workers are registered in order to collect unemployment benefit (normalized to zero). We model the job-brokering service provided by the PEA as follows. All job applications sent by unemployed workers to vacancies registered with the PEA are coordinated so that workers and firms are brought together on a one by one basis. We denote by $a \in (0, 1]$ the maximum number of matching pairs the PEA can propose. a is a technological parameter. The other channel is a search market, which may be referred to as a decentralized or private market. Here, unlike in the PEA, search is costly for workers and workers are unable to coordinate their applications. Workers have to incur an individual specific search cost represented by c drawn from a uniform distribution with support $[0, 1]$. The cost parameter c is uncorrelated with the worker's ex ante type.[13] How workers search without coordination will be specified below.

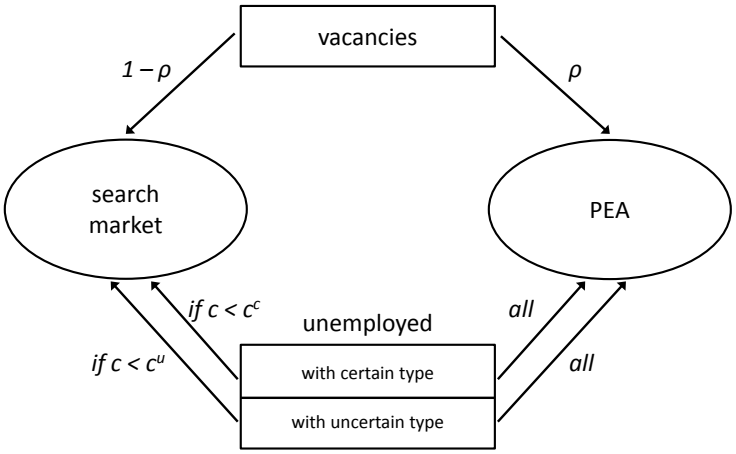

Figure 2: Search channels

The timing is as follows. In the first stage, firms decide whether to post their vacancy in the search market or the PEA. This modeling choice reflects our primary objective of studying why not all firms register in the PEA and is the consistent with the one adopted in Pissarides (1979). In connection with the empirical analysis that follows (especially the one in section 4.3), this choice should be considered as a choice between two wage-offer strategies, rather than being a choice between two search channels. That is, choosing one market is equivalent to choosing a wage offer that is sustainable in equilibrium there. Indeed, we find in our data that that wages paid by vacancies to hired workers depend only

[13] Our main result will go through even if we allow for such a correlation (see Appendix A.10).

on whether vacancies use the PEA as search channel, i.e., their wage-offer strategy, but do not on whether the hired worker was contacted via the PEA or the private market. Once firms are registered, the PEA selects randomly $\min\{v\rho, a\}$ workers, where $\rho \in [0,1]$ is a fraction of firms registered with the PEA, and suggests each of them to match with one of the registered firms. In the second stage, all firms post simultaneously a wage at which they are willing to hire a worker. The wage posted in the search market is denoted by w, and the wage posted in the PEA by w_a. Having observed those wages, workers decide whether or not to enter the search market in the third stage. Once in the search market, workers must choose to which firm to send an application. Each worker sends only one application in the private market. Assuming that workers cannot coordinate their actions over which vacancy to apply, we investigate a symmetric equilibrium where all workers use the identical application strategy for any distribution of announced wages. This is the standard notion of directed search equilibria, see e.g. the recent survey by Wright et al. (2018). Finally, given the applications received via the private market or the worker assigned by the PEA, firms select a productive applicant (if any) and make a job offer. Those workers, who receive multiple offers, can select the highest wage. Once employment decisions are made, production starts and matched workers and firms receive their payoffs. Unmatched workers and firms receive a payoff of zero.

In what follows, we construct a labor market equilibrium which has the following characteristics. A fraction $\rho \in [0,1)$ of firms registered with the PEA post a wage $w_a = 0$ and a fraction $1-\rho$ of firms in the search market post a wage $w \in (0,1)$. All workers are registered in the PEA and accept the wage $w_a = 0$ if it is the only offer they have received. A certain (uncertain) worker enters a search market if and only if his search cost c is no greater than a reservation value c^c (c^u) (see Figure 3), and is hired with probability η ($\delta\eta$) in the search market (yet to be derived endogenously). Each individual firm in the directed search market is characterized by an *effective* queue of applicants,

$$\tilde{x} = \frac{mc^c + \delta(1-m)c^u}{v(1-\rho)}, \tag{1}$$

which measures the expected queue of productive applicants for the job. The numerator equals the total number of productive workers in the search market – mc^c certain and $\delta(1-m)c^u$ uncertain types –, while the denominator equals the total number of vacancies in the search market. Each firm employs a productive worker (and can produce an output of 1) with probability $\tilde{x}\eta$ in the search market and with probability $\min\{1, a/(v\rho)\}(m(1-c^c\eta) + \delta(1-m)(1-c^u\delta\eta))$ in the PEA, where $\min\{1, a/(v\rho)\}$ is the probability of a registered firm to be assigned an unemployed worker by the PEA and $(m(1-c^c\eta) + \delta(1-m)(1-c^u\delta\eta))$ the probability that the assigned worker is productive and available, i.e., does not receive a better-paid offer in the private market. In the following we show that workers and firms have no incentive to deviate from the proposed search market equilibrium.

3.2 Equilibrium with Within Job Variation in PEA Registration

In this section, we make the following assumptions: (a) the information about whether or not an applicant is productive for a job is revealed with no costs at the stage of the job interview; (b) the number of vacancies is exogenously given and the firms' cost required to post a vacancy is normalized to

zero for both markets; (c) the PEA is not able to distinguish the ex-ante type of workers. Assumptions (a) to (c) will be relaxed in section 3.3.

Workers' Search Decision Assuming for the moment the existence of an equilibrium, we first describe workers' search decision. Denote by U^c (U^u) the equilibrium value of searching in the private market for a worker with certain (uncertain) type. Since a worker with certain (uncertain) type and search cost c searches if and only if $c \leq U^c$ ($c \leq U^u$), we can describe the participation decision by a reservation value for the search cost, i.e.,

$$\begin{aligned} c^c &= U^c, \\ c^u &= U^u, \end{aligned}$$

respectively. Given that search costs are uniformly distributed over $[0, 1]$, the threshold values c^c and c^u determine the fraction of certain and uncertain workers that choose to search in the private market. Figure 3 illustrates the search population of certain and uncertain types of workers.

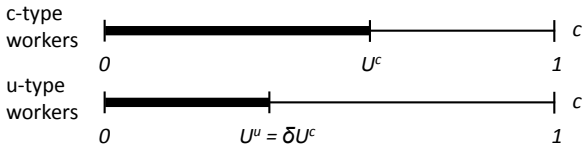

Figure 3: Participation in the search market

Given the participation decision, we now describe workers' application decision in the search market. Each worker observes the wages posted by firms in the private market and forms expectations about the average effective queue of productive workers applying to each vacancy. In order to be able to calculate the expected utility from applying at a particular firm, we first need to compute the probability that a productive applicant gets employed by a firm, η.

Lemma 1 *The employment probability of productive applicants is homogeneous of degree one, and can be written as a function of the effective queue $\tilde{x} \in (0, \infty)$ given by (1), i.e., $\eta = \eta(\tilde{x})$. Further, it satisfies the standard properties of matching functions (see e.g. Pissarides, 2000): $\eta(\tilde{x})$ ($\tilde{x}\eta(\tilde{x})$) is strictly concave and decreasing (increasing) in $\tilde{x}$.*

Suppose a worker observes a firm in the search market with a wage offer $w' > 0$ and an associated effective queue $\tilde{x}'$. Given the employment probability function $\eta(\tilde{x})$, the worker calculates the value of applying to such a firm. In any equilibrium, where U^c is the expected value of search for certain workers offered by the private market, a certain worker will apply to such a firm, if the effective queue $\tilde{x}'$ satisfies,

$$U^c \leq \eta(\tilde{x}')w', \tag{2}$$

because certain workers will be suitable to any firm. Similarly, for uncertain workers it is,

$$U^u \leq \delta\eta(x')w', \tag{3}$$

since the employment probability for an uncertain worker is given by $\delta\eta(\tilde{x}')$. In equilibrium equations (2) and (3) will hold with equality, since firms are not willing to offer workers more than the market utility U^c and U^u. In equilibrium we therefore have $\delta U^c = U^u$ and $\delta c^c = c^u$. Equation (2), which ensures that workers will apply, determines the effective queue of productive workers $\tilde{x}' = \tilde{x}(w'|U^c)$ as a strictly increasing function of the wage w' given the market value U^c (and U^u).

Firms' Wage Offers Given the search behavior of workers described above, the next step is to characterize equilibrium wages. Given the wage offer $w_a = 0$ by firms registered with the PEA (which will be verified shortly), we first derive an equilibrium wage in the search market. In any equilibrium where U^c (U^u) is the market value of a certain (uncertain) worker, the optimal wage of a firm, denoted by $w(U^c)$, satisfies, $w(U^c) = \arg\max_{w'} \Pi_s(\tilde{x}')$ where

$$\Pi_s(\tilde{x}') = \tilde{x}'\eta(\tilde{x}')(1 - w'). \tag{4}$$

Note here that, given $\tilde{x}' = \tilde{x}(w'|U^c)$, the firm takes into account that the higher the offered wage w', the larger the effective queue of productive workers $\tilde{x}'$ and the higher the probability of hiring successfully a suitable (productive) worker. Hence, the standard first order condition implies that firms in the private market will offer a wage $w = w(U^c) > 0$ in equilibrium.

Given the wage offer $w > 0$ in the search market, we show next that the equilibrium wage offer in the PEA must satisfy $w_a = 0$. Given that a proportion $\rho \in [0, 1)$ of firms are in the PEA, the wage $w_a = 0$ in the PEA yields an equilibrium profit,

$$\Pi_a(\tilde{x}) = \min\left\{\frac{a}{v\rho}, 1\right\}\left[m(1 - c^c\eta(\tilde{x})) + \delta(1-m)(1 - c^u\delta\eta(\tilde{x}))\right], \tag{5}$$

where, given the probability of being allocated a worker $\min\{a/(v\rho), 1\}$, the term $m(1 - c^c\eta(\tilde{x}))$ (or $(1-m)(1 - c^u\delta\eta(\tilde{x}))$) represents the expected number of certain (or uncertain) workers, who do not receive a job offer in search markets and are willing to accept $w_a = 0$.

The PEA matches registered workers and firms using its job-brokering mechanism. This allocation is independent of the wages offered by registered firms. The fact that registered firms cannot increase the PEA-internal matching probability $\min\{a/(v\rho), 1\}$ by offering a higher wage implies that registered firms will never compete among themselves. They will only compete with firms in the private market. This is the reason why a wage offer $w_a' \in (0, w)$ cannot be profitable, since such a deviation implies a mere increase in the wage cost without improving the probability of hiring a suitable worker. If a deviating firm posts $w_a' \geq w$, then it can hire an assigned productive worker (if any), irrespective of whether the worker gets another offer in search markets. However, the associated increase in expected productivity is not high enough to be able to compensate for the higher wage cost. This guarantees – together with the absence of PEA-internal wage competition due to the job-brokering mechanism – that $w_a = 0$ is the unique equilibrium wage in the PEA.

Lemma 2 *For any $\rho \in (0, 1)$, the equilibrium wage is higher in the search market than in the PEA, $w > w_a$.*

Firms' Market Choice In the first stage, firms decide whether to enter the PEA or the search market for hiring a worker. Firms will choose the market that offers the highest expected profit. Thereby, the equilibrium condition is given by,

$$\rho = \begin{cases} 0 & \text{if } \Pi_a(\tilde{x}) < \Pi_s(\tilde{x}), \\ (0,1) & \text{if } \Pi_a(\tilde{x}) = \Pi_s(\tilde{x}), \\ 1 & \text{if } \Pi_a > \Pi_s, \end{cases}$$

where the equilibrium effective queue length in the search market $\tilde{x} = \tilde{x}(\rho)$ is given in equation (1) for $\rho \in [0,1)$, and the equilibrium profits $\Pi_s(\tilde{x})$ and $\Pi_a(\tilde{x})$ are given by equation (4) with $\tilde{x}' = \tilde{x}$ and equation (5), respectively. If $\rho = 1$, all firms are in the PEA. By offering the equilibrium wage $w_a = 0$ they earn $\Pi_a = \min\{a/v, 1\}[m + (1-m)\delta]$. Since no jobs are posted in the private market, only workers with zero search costs will participate in it. Hence, if a firm deviates and enters the search market with a wage $w' = \varepsilon > 0$, then the firm meets with a productive worker for sure, and makes profits, $\Pi_s = (1 - \varepsilon)$. This deviation is always profitable for an arbitrary small ε.

Proposition 1 summarizes that a labor market equilibrium with an active PEA exists if the market tightness v exceeds a critical value v^*.

Proposition 1 *A search market equilibrium with an active PEA exists for $v > v^*$, some $v^* \in (0, \infty)$, and with an inactive PEA for $v \leq v^*$. This equilibrium is unique.*

Our theory establishes that despite the high wage costs and coordination frictions in the application stage, some or all firms find it profitable to use the decentralized search market, instead of the PEA. This has two reasons. First, the benefit of using the search market is to obtain a higher chance of receiving an application from a suitable (productive) worker. The second reason is due to the flexibility of the private market. Depending on the market tightness v and the selection of workers the probability of successfully hiring a productive worker can be very high in the private market, while it is fixed in the PEA given the assignment technology of applicants. Also the wage in the decentralized market is lower if the number of firms v is lower, so that the search market is less tight and less competitive. Hence, as shown in Proposition 1, an equilibrium with active search market always exists and is unique.

A dynamic version of our model would lead to a reservation wage above unemployment benefits and would imply that the proportion of suitable (productive) workers in the pool of unemployed would endogenously be lower - due to adverse selection. But qualitatively our results would remain unchanged.

The following three corollaries are immediate consequences of Proposition 1, but derive further implications of the above equilibrium. First, certain types have a better prospect of getting a job offer than uncertain types, because they are productive at any firm. Hence, the high wage offer in the private market induces a high participation rate of certain types, so that the private market can offer a better selection of workers than the PEA does (see Figure 4).

Corollary 1 *The proportion of suitable applicants among all available applicants is higher in the search market than in the PEA, i.e.,*

$$\theta \equiv \frac{m+(1-m)\delta^2}{m+(1-m)\delta} > \frac{m(1-c^c\eta(\tilde{x}))+\delta(1-m)(1-c^u\delta\eta(\tilde{x}))}{m(1-c^c\eta(\tilde{x}))+(1-m)(1-c^u\delta\eta(\tilde{x}))},$$

for any $m \in (0,1)$ *and* $\delta \in (0,1)$.

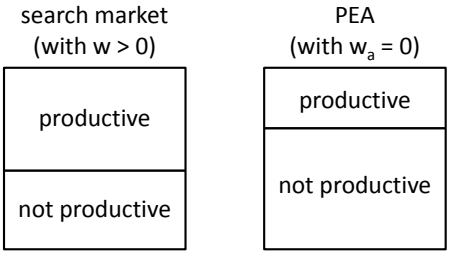

Figure 4: Selection of workers in search market and PEA

Second, by comparing the above equilibrium with the one with no PEA (i.e., the search market is the only avenue of finding a worker/job) we can isolate the role of the PEA in our economy.

Corollary 2 *The PEA creates job opportunities for those, who are discouraged from searching in the private market. The respective share of unemployed is larger among uncertain types (the ones with a lower prospect of finding a job) than certain types.*

The PEA creates this job opportunities for discouraged workers by attracting vacancies, which value the job-brokering services, since it allows them to offer lower wages, and by giving all unemployed workers an equal chance of having an interview. As stated above, this gives rise to the economic value of worker selection in the private market.

Finally, we can contrast our theory with Pissarides (1979), where with homogeneous workers and exogenous wage the private market collapses and all workers search via the PEA, if search frictions in the PEA are eliminated.

Corollary 3 *For the values of technological parameter large enough to make the PEA match the short side, i.e.,* $a \geq \min\{v\rho, 1\}$*, the search market will still be active in equilibrium.*

In our framework with heterogeneous workers and endogenous wages, the higher probability of receiving a suitable (productive) applicant ensures the existence of an active decentralized market even if the PEA manages to match the short side of the market.

3.3 Across Job Variation in PEA Registration

Based on the framework established above, we explore the determinants of vacancies' PEA registration rates across different occupations (types of jobs). In the first part of this section we investigate the effect of changes in the overall fraction of certainly productive workers, m, and the probability that an uncertain worker is productive, δ, (as well as the atching technology of the PEA a). In the second

part we relax our assumptions (a)–(c) one at a time, and analyze how each of these extensions would change the active use of the PEA in comparison with our baseline model. By linking the extensions "interviewing costs", "vacancy creation costs", and "informational advantage of the PEA" to job characteristics we get further hypotheses on the determinants of vacancies' PEA registration rates across different types of jobs.

Comparative Statics

Proposition 2 *The PEA is more likely to be active when the overall fraction of certainly productive workers, m, the probability that an uncertain worker is productive, δ, or the matching technology of the PEA, $a < \rho v$, is higher.*

The intuition behind this result is that with a higher overall fraction of certainly productive workers, m, or a higher probability that an uncertain worker is productive, δ, the advantage of having a better chance of receiving productive applicants in the search market compared to the PEA is reduced. This increases the attractiveness of the PEA and makes it more likely that it is used. A higher matching efficiency in the PEA (as long as $a < \rho v$) will make the PEA more attractive and simply increases the fraction of firms that register with the PEA.

The proportion of certainly productive workers, m, and the probability that an uncertain worker is productive, δ, is likely to vary across occupations. In section 4.4 below, we use our theory to obtain occupation specific values for m and δ from the occupation specific data on the fractions of suitable applicants among applicants coming via the PEA and via the private market and show that the relation predicted in Proposition 2 can be found in the data.

Extensions In the labor market equilibrium established in our baseline model, both labor market institutions can coexist. By extending the baseline model, we show that the PEA is likely to be active when (a) interview costs and (b) vacancy creation costs are low, and when (c) the PEA has an information advantage about workers' types compared to the private market. Low interview costs and low vacancy creation costs are the typical characteristics of simple jobs, which require only a low level of qualification.

To address the first extension, suppose that a job interview requires a fixed cost, denoted by $f \geq 0$, and that the total interviewing cost of a firm is proportional to the number of applicants it receives.[14] The number of applicants each firm receives (and interviews it makes) is at most one in the PEA while it is random in the search market. The total interview costs of firms are f in the PEA and $\tilde{x}f/\theta$ on average in the search market, where θ is the share of suitable (productive) applicants in the search market and so $\tilde{x}/\theta$ is the queue of workers (both productive and unproductive). With this extension, we have the following result.

[14]The latter assumption implies that firms process all their applications. Alternatively, one can instead assume that interviews occur sequentially, and firms may not need to interview all their applicants. This can be incorporated into our setup as well. Note, however, that our aim here is to show that our main result survives despite costly interviews. We therefore adopt the most disadvantage technology to firms in the search market. Hence, the main result will be robust to a sequential interviewing technology as modeled by Wolthoff (2016).

Proposition 3 *(**Interviewing Costs**): Suppose there is a cost of interviewing an applicant, $f > 0$. Then, a search market equilibrium with an active PEA exists as long as f is not too high. For relatively high f, the PEA is inactive and only the search market exists.*

The PEA is not attractive when interviewing costs are high, because registered firms have to cover the interview cost alone whereas in the private market the interview cost is partly passed on to unemployed workers via a lower wage. Thus, higher interview costs reduce profits of registered firms more than profits of unregistered firms.

In the next extension, suppose that vacancy creation requires costs denoted by $K \in (0, 1)$ and that the number of vacancies is determined by a *free entry* condition,

$$\max\{\Pi_a, \Pi_s\} = K,$$

where $\Pi_a = \Pi_a(\tilde{x})$ is given by (5) and $\Pi_s = \Pi_s(\tilde{x})$ by (11). Whenever the search market exists, its effective queue $\tilde{x}$ is determined by this free entry condition.

Proposition 4 *(**Vacancy Creation Costs**): With free entry of firms, a search market equilibrium exists with an active PEA for low values of K, and with an inactive PEA for high values of K.*

A search market exists for any $K \in (0, 1)$, since free entry ensures that the queue length $\tilde{x}$ will adjust in such a way that profits in the search market are equal to vacancy creation costs. Note, that profits in the PEA cannot adjust as flexibly as in the private market, since wages and the allocation technology a remain constant. Consequently, firms cease to use the PEA even for vacancy creation costs that still ensure an active search market.

As a final extension we analyze what happens if the PEA knows more about unemployed workers than firms do. Suppose now that the PEA is able to observe the (ex ante) type of workers – certain or uncertain –, and distributes certain workers prior to uncertain workers. The information advantage may occur due to the frequent interactions between the registered unemployed and the case manager, and backed by the accumulated knowledge from past experiences. Given such an ability of the PEA, if

$$\min\{a, v\rho\} \leq m, \tag{6}$$

then all applicants that the PEA distributes are productive workers. This yields an equilibrium profit of a firm,

$$\Pi_a(\tilde{x}) = \min\{\frac{a}{v\rho}, 1\}(1 - c^c\eta(\tilde{x})), \tag{7}$$

where, given that an applicant is productive for sure, the term $1 - c^c\eta(\tilde{x})$ represents the probability that an applicant assigned to the firm has not received a job offer in the search market and is willing to accept $w_a = 0$. As before, any deviation from $w_a = 0$ is not profitable. Note, however, that if condition (6) does not hold, also uncertain workers will be distributed. This decreases the average productivity of those workers distributed by the PEA and increases the incentive of firms to use the private market.

Proposition 5 *(**Informational Advantage of the PEA**): Suppose that the PEA can observe the (ex ante) type of workers, and distribute certain workers prior to uncertain workers. Then, the PEA will become more likely to be active relative to the baseline setup. Search markets will be inactive if and only if* $\min\{a, m\} \geq v$.

The PEA can prevent workers and firms from using the private market if it is able to allocate a productive applicant to every registered vacancy. We should note, however, that even with such an ability, search markets become active when the population of certain types is scarce, i.e., m is small. The fact that the majority of firms use the private market only suggests either that the PEA has no informational advantage or that the fraction of certainly productive worker m is sufficiently small. In section 4.4 below, we show that the estimated occupation specific fractions of certainly productive workers m_i are in the range between 0.1% and 47.6%.

To the extent that for high (low) qualification jobs the amount of information needed to identify the suitability of applicants is relatively high (low), the extended model with interview costs predicts that jobs, which require a high (low) qualification level and hence higher (lower) interview cost are less (more) likely to register with the PEA. The same is true, if we assume that jobs, which require less qualification, are less costly to create (relative to output, which we normalized to one), the model extension with endogenous vacancy creation then predicts – as before – that jobs with a lower qualification requirement are more likely to register with the PEA. In section 4.4 we present empirical evidence, which support these hypotheses.

4 Empirical Analysis

We will first introduce the data sets used in this paper. Then, we will investigate whether we can find in the data the forces, which explain theoretically that only a fraction of firms register their vacancies with the PEA, i.e., that the share of suitable applicants is lower among applicants coming from the PEA compared to the private market and that wages paid by registered jobs are lower. In the second part we will test whether occupations with an higher overall fraction of certainly productive workers and with a higher probability that uncertain workers are suitable have a higher PEA registration rate. We will also test whether temporary job or jobs, which require a low qualification level, are more likely to register with the PEA.

4.1 Data

For our analysis we use two data-sets. The German Job Vacancy Survey, which contains information about firms' recruitment process, and the German Socio Economic Panel (GSOEP), which contains - among other things - wage information from the workers' side.

German Job Vacancy Survey

The German Job Vacancy Survey is collected by the Institute for Employment Research in German.[15] It is based on a representative sample of establishments, which is newly sampled each year. The

[15]The data used in this article were made available to us by the Research Data Centre of the German Federal Employment Agency at the Institute for Employment Research (IAB), Nuremberg.

yearly survey started in 1989 and was initially conducted to provide an estimate of the total number of vacancies in Germany relative to the number of vacancies registered with the PEA.

The survey includes establishment level data on the number of employees, number of vacancies, hires and quits in the last 12 months, and information on the industry and region of the firm. The economic conditions of a firm can be proxied by binary indicator variables for "low sales", "financial constraints", and "skilled labor shortage". It also contains a number of questions concerning the last case of a successfully filled vacancy. In this part of the survey firms were asked which search channels they used and through which channel they hired. Since we are interested in the implications of searching in a private market versus the PEA, we exclude those vacancies, where the hiring firm exclusively used a recruitment channel like the internal job market, recommendations by employees, or former apprentices or interns. The survey also provides information on the number of applicants, the number of suitable applicants, the qualification and experience level required for the job, information on job characteristics like occupation, permanent/temporary, full-/part-time, and weekend-work required. The data also contains information on whether a firm experienced difficulties in the recruitment process due to "high wage demands" of applicants, which we use as one piece of evidence to investigate the existence of a wage difference between registered and unregistered vacancies. Data on wages paid to newly hired workers is only available for the year 2014. We also have some information on the newly hired worker like the age, gender, and the previous employment status.

To test the hypothesis that the share of suitable applicants is lower among applicants coming from the PEA we can use the information on the number of applicants and the number of suitable applicants in total and the number of applicants and the number of suitable applicants sent by the PEA for the same (registered) vacancy.[16] This information is available for registered vacancies in the years 2005 to 2008.

In our analysis we use the full sample and a subsample, which only includes vacancies that were successful in filling their vacancy before the intended starting data of the employment contract. The subsample is referred to as the restricted sample. We prefer this subsample, since it excludes cases in which a firm might rethink its search strategy after having failed to find a worker within the expected time. We want to exclude such cases in order to rule out reverse causality.

German Socio Economic Panel

To complement the analysis on wages using the workers' perspective, we use data from the German Socio Economic Panel (GSOEP). The GSOEP is a longitudinal survey of German households, which started in 1984 and is conducted on the annual basis ever since.[17] The GSOEP is the largest and most comprehensive household panel in Germany.

For our analysis we use the information on the search behavior of non-employed individuals and the wages earned in their subsequent job. For the years 2005 to 2007 non-employed in the GSOEP were asked whether they search actively for a job in the last four weeks. From this group of workers

[16]The precise questions are "If you have searched via the PEA, how many applicants did the PEA send to you?" and "How many suitable applicants were among them?"

[17]The data used in this article is part of the German Socio-Economic Panel Study (SOEP), which is made available by the German Institute for Economic Research (DIW), Berlin.

we selected all non-employed workers below the age of 60, who send at least one application.[18] For them we have the information on the search channels they used (PEA, job ads, internet, network, speculative application) and a host of personal characteristics including whether they are registered as unemployed with the PEA. For non-employed worker, who found a job within the next year, we know the search and hiring channel through which they obtained the job and the hourly gross wage of the job. Since there are only 423 observations for this group of non-employed job seekers, who found a job in the subsequent year, we cannot control for worker-fixed effect. To control for worker-fixed effects we alternatively use the larger sample of employed workers from 2003 to 2013, for whom we only know whether the PEA was used as hiring channel. For this group we have no information on the search channels used to find the job.

4.2 Differences in the Fraction of Suitable Applicants

The main insight of our theory is the positive self-selection of workers into the private market (Corollary 1).

Hypothesis 1: *The fraction of suitable applicants is higher among applicants from the private market than among applicants sent by the PEA.*

In Table 1 we investigate to which extent firms regard applicants sent by the PEA less often as suitable compared to those, who applied through the private market. To do so we use within vacancy variation, i.e., for each registered vacancy in the years 2005 to 2008 the information on the share of suitable applicants among the applicants coming via the PEA and among applicants coming via the private market. Since the respective shares are calculated for the same vacancies, we are able to control perfectly for all vacancy characteristics. Table 1 presents the respective difference results for the full and the restricted sample.

Table 1: **Fraction of suitable applicants**

	Fraction of suitable applicants through			
	PEA	private market	difference	N
full sample	0.3348	0.3826	-0.0478**	3,270
	(0.0060)	(0.0058)	(0.0082)	
restricted sample	0.3695	0.3915	-0.0220*	1,872
	(0.0081)	(0.0077)	(0.0109)	

Source: German Job Vacancy Survey 2005-2008.
The restricted sample only includes vacancies, which were successful in hiring an applicant before the intended starting date.
Robust standard errors in brackets. ** indicates $p < 0.01$; * $p < 0.05$.

Table 1 shows that the fraction of suitable applicants sent by the PEA is significantly lower than the respective fraction of suitable workers, who applied through the private market. The difference in

[18] We exclude workers above the age of 60, since they can receive unemployment benefits without actively searching for a job.

the fraction of suitable applicants of 2.2 to 4.8 percentage points is equivalent to 5.7% to 12.5% taking into account the fraction of suitable applicants of 38.3% to 39.2%. We also investigate the difference in the fraction of suitable applicants for different types of vacancies in order to see whether the effect is driven by certain subgroups. Table B.2 in the Appendix shows the respective difference estimates. The difference in the fraction of suitable applicants is statistically significant for most subgroups of vacancies. The lack of significance for some subgroups is likely to be driven by the low number of observations in these subgroups.

To be able to control for all vacancy characteristics, we included in the previous sample (in Table B.2) only vacancies, which were registered with the PEA and for which we have data on the fraction of suitable applicants from both the PEA and the private market. In order to check the external validity of our results, we present in Table B.3 in the Appendix results of OLS regressions for all registered and not registered vacancies. The coefficient for the indicator variable for using the PEA as search channel shows that using the PEA is associated with a 4.2 to 4.6 percentage points increase in the overall fraction of suitable applicants. These results suggest that this differences in the fraction of suitable applicants holds in general.

Given the observation that the fraction of suitable applicants sent by the PEA is lower than the respective fraction of suitable workers, who applied through the private market, and the evidence by the empirical literature using individual-level data,[19] we believe that the pool of workers at the PEA (i.e., registered unemployed) is indeed a negative selection of the average applicant. Our analysis is the first to provide evidence for this negative self-selection from the firms' perspective. This is important, because it suggests that the PEA either has no informational advantage or – that in case it has an informational advantage – it does not want to use it in its matching procedure.[20]

4.3 Wage differences

In this subsection we investigate from the vacancy's and the worker's perspective how the intermediation services provided by the PEA influence wages. We start our investigation by looking at the information available in the German Job Vacancy Survey.

Wages paid by registered compared to unregistered vacancies

Hypothesis 2: *Wages posted and paid by firms registered with the PEA are lower than wages posted and paid by firms only active in the private market.*

To investigate this hypothesis we first use the German Job Vacancy Survey in 2014, which – for the first time – collected the information on the wages paid to the hired workers. A first look at the

[19] Using a US household survey Blau and Robins (1990) show that unemployment insurance and welfare recipients are more likely to use the PEA. Using the Canadian Labor Force Survey Osberg (1993) emphasizes the importance to control for sample selection into PEA use. Using the British Labour Force Survey Gregg and Wadsworth (1996) find that PEA use is highest among less skilled and long-term unemployed workers. Holzer (1988) uses the Youth Cohort of the National Longitudinal Survey to analyze the self-selection of workers and concludes that PEAs are primarily used by individuals with few job opportunities.

[20] Given its non-discrimination policy it is quite plausible that the PEA would not want to use an informational advantage in its matching procedure.

descriptive statistics is affirmative. A worker hired for a job, which was registered with the PEA, earns on average paid 12.84 Euros per hour. This is 2.34 Euro less than the 15.18 Euros per hour, which workers earn at jobs offered purely in the private market.

The descriptive difference could be driven by the heterogeneity between registered and unregistered vacancies. In the OLS-regressions in Table 2 we control for the worker-, firm-, and vacancy characteristics. The German Job Vacancy Survey provides information on age, gender and previous employment status of the hired worker. The information on age and the job's qualification requirement allows us to calculate the potential labor market experience of the hired worker. To do so we use job qualification requirements to approximate the years of schooling. Variables that control for vacancy characteristics include the occupation, the required qualification and experience level, whether it is a permanent or temporary and full-time or part-time job. We also include the indicator variables, which captures whether the vacancy was registered with the PEA (PEA search channel) and hired a worker found through the PEA (PEA hiring channel). On the firm level we include the number of employees (log), an indicator variable if the firm is unionized, and the binary indicator variables "low sales", "financial constraints", and "skilled labor shortage" to control for the economic condition of the firm. We also control for region- and industry-fixed effects. The results show that wages paid by firms that registered their vacancy at the PEA are 3.2 to 4.2 percentage points lower than wages paid by unregistered vacancies.

Our control variables allow us to rule out alternative explanations for the observed PEA wage gap. By controlling for firm size as well as indicator variables concerning "low sales", "financial constraints", and "skilled labor shortage" we are able to control for a possible selection of less productive firms into registering with the PEA. Controlling for worker characteristics like age, gender, experience, and most importantly the previous employment status, implies that the remaining wage difference is not driven by a negative selection of workers into unemployment or by the negative signal attached to the unemployment status. The PEA wage gap can also be found for different submarkets as shown in Table B.4 in the Appendix, which shows the results for different types of vacancies.

Table 2 presents in columns (1) and (2) the OLS-regression results on (log) wages for the full sample and in columns (3) and (4) for the restricted sample. In the latter we exclude all those observations where firms agreed on an applicant after the intended starting date of the employment contract. The restricted sample should therefore rule out reverse causality, i.e., that firms, which were not successful in filling the vacancy before the intended starting date of the employment contract, adjusted their wage offer and search strategy by registering the vacancy with the PEA. We therefore regard the results in columns (3) and (4) as being more reliable.

Comparing columns (3) with column (4) shows that the effect is robust to including an indicator variable for cases where the worker is hired through the PEA. The fact that the coefficient on the "PEA hiring channel" indicator variable is not statistically significant suggests that wages offered by firms do not depend on whether the worker was hired through the PEA. What matters is whether a firm registered its vacancy with the PEA, i.e., used the PEA as a search channel. Put differently, the insignificance of the "PEA hiring channel" suggests that firms do not adjust their wage depending on

Table 2: **Wage difference between registered and unregistered vacancies**

	OLS-Regressions: Wages (log)			
	full sample		restricted sample	
	(1)	(2)	(3)	(4)
PEA search channel	-0.0313**	-0.0268**	-0.0487**	-0.0418**
	(0.0058)	(0.0064)	(0.0090)	(0.0099)
PEA hiring channel		-0.0163		-0.0249
		(0.0092)		(0.0148)
previously unemployed	-0.0569**	-0.0550**	-0.0558**	-0.0532**
	(0.0064)	(0.0065)	(0.0098)	(0.0099)
worker's experience	0.0134**	0.0134**	0.0152**	0.0152**
	(0.0010)	(0.0010)	(0.0015)	(0.0015)
worker's experience^2	-0.0003**	-0.0003**	-0.0003**	-0.0003**
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
female	-0.0650**	-0.0651**	-0.0688**	-0.0691**
	(0.0079)	(0.0079)	(0.0118)	(0.0118)
low qualification	-0.0997**	-0.0998**	-0.1004**	-0.1006**
	(0.0116)	(0.0116)	(0.0175)	(0.0175)
high qualification	0.2201**	0.2198**	0.2238**	0.2235**
	(0.0135)	(0.0135)	(0.0190)	(0.0190)
occupation specific experience	0.0724**	0.0721**	0.0720**	0.0718**
	(0.0068)	(0.0068)	(0.0099)	(0.0099)
permanent	0.0464**	0.0462**	0.0571**	0.0570**
	(0.0057)	(0.0057)	(0.0085)	(0.0085)
full-time	0.0046	0.0046	0.0121	0.0126
	(0.0099)	(0.0099)	(0.0143)	(0.0143)
weekend-work	-0.0294**	-0.0297**	0.0309**	0.0316**
	(0.0096)	(0.0096)	(0.0140)	(0.0140)
unionized firm	0.0747**	0.0743**	0.0776**	0.0773**
	(0.0065)	(0.0065)	(0.0101)	(0.0101)
firm size (log)	0.0287**	0.0285**	0.0341**	0.0336**
	(0.0026)	(0.0026)	(0.0040)	(0.0040)
"financial constraints"	-0.0096	-0.0091	-0.0151	-0.0139
	(0.0162)	(0.0162)	(0.0247)	(0.0247)
"low sales"	0.0048	0.0050	-0.0048	-0.0049
	(0.0098)	(0.0099)	(0.0146)	(0.0146)
"skilled labor shortage"	-0.0147	-0.0150	0.0034	0.0033
	(0.0082)	(0.0082)	(0.0147)	(0.0147)
region-, occup.-, ind.-FE	yes	yes	yes	yes
R^2	0.6789	0.6790	0.6829	0.6831
N	6,523	6,523	3,203	3,203

Source: German Job Vacancy Survey 2014.
The restricted sample only includes vacancies, which were successful in hiring an applicant before the intended starting date.
Robust standard errors in brackets. ** indicates $p < 0.01$; * $p < 0.05$.

the channel through which the preferred worker contacted them, but commit to a wage ex-ante. This is well in line with our directed search framework and supports our assumption that firms choose a certain wage policy (competitive wage, which is attractive for private market job applicants, versus reservation wage, which relies on the intermediation services of the PEA for applicants).

Differences in experiencing difficulties due to "high wage demands"

The German Job Vacancy Survey also contains a question on whether a firm had difficulties in filling the vacancy because its applicants demanded higher wages. This information can shed light not only into the question on whether registered vacancies offer lower wages than unregistered vacancies, it

also provides information on whether a worker receives different wage offers from registered compared to unregistered vacancies.

Given the evidence presented above that registered vacancies pay lower wages, we expect that they are also more likely to experience difficulties in the hiring process due to higher wage demands by applicants. This is indeed the case. Registered vacancies experience such difficulties in 7.8% of all cases, while unregistered vacancies experience such difficulties only in 3.5% of all cases. In Table 3 we use the same job- and firm-characteristics as control variables as in Table 2. We do not include individual characteristics of the hired worker, since the question underlying the indicator variable "difficulties due to high wage demands" explicitly addresses the experience with all applicants.

Table 3: **Recruiting difficulties due to "high wage demands"**

	Recruiting difficulties due to "high wage demands" Probit Regressions: Marginal Effects			
	full sample		restricted sample	
	(1)	(2)	(3)	(4)
PEA search channel	0.0388**	0.0415**	0.0377**	0.0412**
	(0.0042)	(0.0046)	(0.0052)	(0.0059)
PEA hiring channel		-0.0075		-0.0098
		(0.0055)		(0.0069)
low qualification	0.0319**	0.0320**	0.0255*	0.0255*
	(0.0084)	(0.0084)	(0.0104)	(0.0104)
high qualification	-0.0247**	-0.0248**	-0.0235*	-0.0237*
	(0.0088)	(0.0087)	(0.0106)	(0.0105)
occupation specific experience	0.0044	0.0043	0.0014	0.0013
	(0.0046)	(0.0046)	(0.0058)	(0.0058)
permanent	0.0086	0.0084	0.0022	0.0019
	(0.0049)	(0.0049)	(0.0059)	(0.0060)
full-time	0.0033	0.0033	0.0062	0.0062
	(0.0065)	(0.0065)	(0.0073)	(0.0073)
weekend-work	0.0007	0.0006	0.0014	0.0012
	(0.0073)	(0.0073)	(0.0090)	(0.0090)
firm size (log)	-0.0030	-0.0031	-0.0049*	-0.0050*
	(0.0018)	(0.0018)	(0.0021)	(0.0021)
"financial constraints"	0.0340**	0.0341**	0.0338**	0.0340**
	(0.0079)	(0.0079)	(0.0092)	(0.0092)
"low sales"	0.0242**	0.0242**	0.0135	0.0135
	(0.0063)	(0.0063)	(0.0077)	(0.0077)
"skilled labor shortage"	0.0556**	0.0553**	0.0539**	0.0534**
	(0.0065)	(0.0065)	(0.0086)	(0.0087)
year-, region-, occup.-, ind.-FE	yes	yes	yes	yes
(year x region)-FE	yes	yes	yes	yes
Pseudo-R^2	0.1406	0.1409	0.1636	0.1642
N	12,745	12,745	6,493	6,493

Source: German Job Vacancy Survey 2005-2008.
The restricted sample only includes vacancies, which were successful in hiring an applicant before the intended starting date.
Robust standard errors in brackets. ** indicates $p < 0.01$; * $p < 0.05$.

The results in Table 3 indicate a strong positive correlation between registering a vacancy with the PEA and experiencing difficulties in the recruitment process due to high wage demands by applicants. Thus, registering a vacancy with the PEA (and posting the respective low wage) is associated with

an increase in the probability to experience difficulties due to higher wage demands by 3.8 to 4.1 percentage points. The effect is virtually the same if we exclude all observations where firms agreed on an applicant after the intended starting date of the employment contract (restricted sample in columns (3) and (4)). Whether a firm hired the worker through the PEA has no influence on the probability to experience difficulties in the recruitment process due to higher wage demands. The same pattern holds if we divide the sample into different subgroups as shown in Table B.5 in the Appendix.

Wages earned by workers using the PEA as search and hiring channel

In this section we use the GSOEP to investigate the question from the worker's perspective. According to our theory workers are offered lower wages by firms registered with the PEA compared to wages offered by unregistered firms. If workers receive multiple offers, they will accept the higher offer. Thus, the wage earned will depend on the channel through which the worker was hired. Whether the PEA was used as search channel by the worker should not matter.

Hypothesis 3: *Earned wages are lower if a worker is hired through the PEA. Using the PEA as search channel has no influence.*

The information on the search channels used is only available in the years 2005 to 2007. If a non-employed worker finds a job within the next year we have the information to calculate the hourly gross wage. We restrict ourselves to workers employed at regular full-time and part-time jobs, i.e., exclude mini jobs and apprenticeships. If the PEA was directly involved in the hiring process, we refer to it as having initiated the hiring. This information is available from 2003 onward. Given that the information on the PEA search channel used by non-employed is only available in the years 2005 to 2007, the observations are so few that we cannot use the panel structure to control for individual fixed effects. Nevertheless we present these OLS results in column (1) in Table 4 in order to provide some evidence on how the PEA search channel in interaction with the PEA hiring channel is correlated with the hourly gross wage. In columns (2) and (3) we present results using data from 2003 to 2013. Here we only know whether the PEA was used as hiring channel, but we have no information on the search channels used. We include again only regular full-time and part-time jobs. Column (3) shows our preferred wage regression with individual fixed effects. In column (2) we include OLS estimates for the same sample in order to get an idea about the likely bias caused by not using individual fixed effects.

In Table 4 we present a standard Mincer wage regression with work and unemployment experience, work and unemployment experience squared, and educational indicator variables according to the ISCED 1997 classification. We also include an indicator variables for being registered as unemployed in the previous year, for a permanent job, and for six firm size groups, as well as year and occupation fixed effects (ISCO classification).

The result in column (1) in Table 4 supports our hypothesis that using the PEA as hiring channel leads to a lower hourly gross wage while using the PEA as search channel has no influence. However, due to the small sample size of 423 observations for employed workers we cannot control for individual

Table 4: **Workers: Differences in wages earned in case of PEA intermediation**

	First year hourly gross wages (log) of ...		
	previous non-employed	regular employed	
	OLS	OLS	FE-regression
	(1)	(2)	(3)
PEA search channel	-0.0087		
	(0.0610)		
PEA hiring channel	-0.1863*	-0.0824**	-0.0287*
	(0.0769)	(0.0139)	(0.0134)
previously reg. unempl.	-0.0680	-0.1066**	-0.0518**
	(0.0653)	(0.0084)	(0.0083)
work experience	0.0113	0.0284**	0.0520**
	(0.0067)	(0.0005)	(0.0013)
work experience^2	-0.0002	-0.0005**	-0.0006**
	(0.0002)	(0.0000)	(0.0000)
unempl. experience	-0.0708**	-0.0820**	-0.1040**
	(0.0147)	(0.0022)	(0.0139)
unempl. experience^2	0.0030**	0.0046**	0.0069**
	(0.0008)	(0.0003)	(0.0020)
permanent job	0.0553	0.0259**	-0.0249**
	(0.0455)	(0.0046)	(0.0030)
female	-0.1307*	-0.1750**	
	(0.0563)	(0.0033)	
general elementary	0.0882	0.0107	
	(0.1384)	(0.0101)	
middle vocational	0.0862	-0.0007	
	(0.1235)	(0.0095)	
vocational & high school	0.3360*	0.0736**	
	(0.1410)	(0.0103)	
higher vocational education	0.1340	0.0665**	
	(0.1402)	(0.0104)	
higher education	0.2223	0.1682**	
	(0.1418)	(0.0102)	
year-, occup., firm-size-FE	yes	yes	yes
individual-FE	no	no	yes
R^2	0.5817	0.4521	0.1021
N	423	98,501	98,501

Source: German Socio Economic Panel, (non-employed) 2005-2007, (regular empl.) 2003-2013.
Robust standard errors in brackets. ** indicates $p < 0.01$; * $p < 0.05$.

fixed effects. We are therefore cautious and do not interpret the size of the coefficients. To get a more reliable estimate for the effect that a direct involvement of the PEA has on the gross hourly wage, we present in column (3) of Table 4 a fixed-effects regression. The coefficient for the PEA hiring channel indicator variable suggests that the direct involvement of the PEA goes along with a wage difference of 2.9 percentage points. This difference is in line with the 2.7 to 4.2 percentage points wage difference found between registered and unregistered vacancies in Table 2 (column (2) and (4)). The evidence provided in Table 4 therefore supports our theoretical model.

4.4 PEA registration across occupations

The proportion of certainly productive workers, m, and the probability that an uncertain worker is productive, δ, are according to our theory driving forces for use of the PEA as search channel. We can use our theory to obtain the following formulas, which link m and δ to the fractions of suitable applicants among applicants coming via the PEA, f^{PEA}, and via the search market, f^{SM}, i.e.,

$$f^{PEA} = m + \delta\,(1-m) \text{ and } f^{SM} = \frac{m + \delta^2\,(1-m)}{m + \delta\,(1-m)}$$

imply

$$\delta = f^{PEA}\frac{1-f^{SM}}{1-f^{PEA}} \text{ and } m = \frac{f^{PEA}\left(f^{SM}-f^{PEA}\right)}{1-f^{PEA}-f^{PEA}\,(1-f^{SM})}. \tag{8}$$

Using these formulas we calculate occupation specific values for m and *delta* from the occupation specific fractions of suitable applicants f^{PEA} and f^{SM}.

In order to be able to compare occupation specific fractions of suitable applicants across occupations, we need to hold the set of job and firm characteristics constant. We do this by first regressing observable job and firm characteristics on the fraction of suitable applicants at the vacancy level (separately for applicants coming via the PEA and via the private market).[21] In the second step, we set the observable job and firm characteristics equal to the sample average and predict the occupation specific fractions of suitable applicants using the regression results. Given the estimates for the occupation specific fractions of suitable applicants f^{PEA} and f^{SM} we calculate the respective occupation specific values for the proportion of certainly productive workers, m, and the probability that an uncertain worker is productive, δ using the formulas in (8).

On average around 9.1% of all job seekers are estimated to be certainly productive (m is on average 9.1%). The estimates for m range from 0.1% to 47.6%. The estimates for δ range from 0.0% to 58.1%. On average an uncertain worker is estimated to be productive in 22.2% of all cases. The occupation specific values for m and *delta* are positively correlated with the occupation specific PEA registration rate with a pairwise correlation coefficient of 33.6% and 34.5% as Proposition 2 predicts. The measures m and δ are almost uncorrelated with a pairwise correlation coefficient of 1.6%.

Columns (1) and (2) of Table 5 present OLS regressions on the occupation-level explaining the occupation specific PEA registration rates without and with the occupation specific measures m and δ. In the first two rows we present the estimates for the occupation specific proportion of certainly productive workers, m, and the occupation specific probability that an uncertain worker is productive, δ. The results show that a one percentage point increase in the proportion of certainly productive workers increases the occupation specific PEA registration rate by 0.74 percentage points, and a one percentage point increase in the probability that an uncertain worker is productive increases the occupation specific PEA registration rate by 0.44 percentage points. These are sizable effects. Comparing column (1), where we omitted m and δ, with column (2) shows that adding the occupation specific proportion of certainly productive workers, m, and the occupation specific probability that an

[21] The sample for the OLS regression explaining the fraction of suitable applicants coming via the PEA contains all registered vacancies with the respective information on the number of (suitable) applicants in the restricted sample. The sample for the OLS regression explaining the fraction of suitable applicants coming via the private market contains all non-registered vacancies in the restricted sample.

uncertain worker is productive, δ, increases the R^2 from 15.5% to 33.8%. Thus, m and δ are able to explain 18.3% of the total variation in PEA registration rates across occupations. All other job- and firm-characteristics are on the occupation level far less important.

Column (3) of Table 5 presents marginal effects of a probit regression explaining the use of the PEA as search channel on the vacancy level. The occupation specific proportion of certainly productive workers, m, and the occupation specific probability that an uncertain worker is productive, δ, have again sizable effects. A one percentage point increase in the proportion of certainly productive workers increases the probability that a vacancy uses the PEA as search channel by 0.41 percentage points and one percentage point increase in the probability that an uncertain worker is productive by 0.31 percentage points.

Table 5: **PEA registration**

	Characteristics associated with PEA registration		
	occupation-level		vacancy-level
	OLS regressions		Probit Regressions (ME)
	(1)	(2)	(3)
m - prob. of uncert. work.		0.7440**	0.4074**
		(0.1630)	(0.1183)
δ - prop. of cert. prod. work.		0.4378**	0.3141**
		(0.0917)	(0.0690)
low qualification	0.1558	0.1172	0.0275
	(0.1001)	(0.0898)	(0.0227)
high qualification	0.0310	0.0565	-0.0424**
	(0.0443)	(0.0409)	(0.0141)
occupation specific experience	0.1109	0.0825	0.0026
	(0.0633)	(0.0566)	(0.0115)
permanent	0.0158	0.0235	-0.0192
	(0.0569)	(0.0510)	(0.0121)
full-time	-0.0268	-0.0038	0.0599*
	(0.0766)	(0.0688)	(0.0146)
weekend-work	0.0663	0.0493	-0.0477**
	(0.0558)	(0.0498)	(0.0164)
firm size (log)	-0.0368*	-0.0268	-0.0169**
	(0.0163)	(0.0148)	(0.0041)
"financial constraints"	0.1430	0.0902	0.0516*
	(0.1483)	(0.1332)	(0.0205)
"low sales"	0.1557	0.1879	0.0368*
	(0.1118)	(0.1003)	(0.0176)
"skilled labor shortage"	0.3266*	0.3057*	0.1352**
	(0.1636)	(0.1458)	(0.0237)
year-, region-, ind.-FE	no	no	yes
(year x region)-FE	no	no	yes
R^2/ Pseudo-R^2	0.1548	0.3379	0.0525
N	178	178	7,296

Source: German Job Vacancy Survey 2005-2008, restricted sample only.
Robust standard errors in brackets. ** indicates $p < 0.01$; * $p < 0.05$.

Column (3) of Table 5 also shows which other vacancy characteristics are associated with using the PEA as search channel. Jobs, which require a high qualification level are less likely to be registered with the PEA than job requiring a medium or low qualification level. If jobs, which require a high

qualification level are associated with higher job creation costs and/or interview costs, then this supports our hypothesis that high job creation and/or interview costs make it less likely that a vacancy is registered with the PEA.

5 Conclusion

We investigate the implications for the labor market of having a Public Employment Agency (PEA), which provides an additional market place with lower coordination frictions. This is an unexplored issue in the labor economics literature. We develop a new theoretical model, where firms can decide whether to offer a competitive wage, which is attractive to private market job seekers, or to offer the reservation wage and rely on the intermediation services of the PEA for applicants. We show that lower coordination frictions in the PEA reduce wage competition and enable registered firms to pay lower wages compared to the private market. This advantage has to be traded off against the negative selection of applicants coming through the PEA compared to the private market. Further, our theory explains in which occupations it is more likely that vacancies use the PEA as search channel. We take these (and other) theoretical predictions to the data and find strong support for them.

An interesting topic for future research would be to assess the effect of labor market reforms, e.g. the so-called Hartz Reform in Germany, since part of the reform package (Hartz III) aimed at restructuring the Public Employment Agency. To evaluate this part of the Hartz Reform, it would be necessary to extend the model and data to incorporate other parts of the reform – creating new types of employment opportunities (Hartz I), introducing additional wage subsidies (Hartz II), and cutting unemployment benefits for the long-term unemployed (Hartz IV). We believe our framework - if incorporated into a structural search model like in Krause and Uhlig (2012) and Launov and Wälde (2014) - will best fit to study the effects of the Hartz reforms, especially its effects on unemployment and wage inequality.

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A Appendix: Proofs

A.1 Proof of Lemma 1

Given the search behaviors of workers, each individual firm in the directed search market is characterized by a queue of applicants, denoted by x. The number of applicants $n = 1, 2, 3, ...$ each

individual firm receives is a random variable and follows from a Poisson distribution with density $\text{Prob}[n=\tilde{n}] = \left(x^{\tilde{n}}e^{-x}\right)/(\tilde{n}!)$. The effective queue of applications is $\tilde{x} = \theta x$ where

$$\theta \equiv \frac{mc^c + \delta(1-m)c^u}{mc^c + (1-m)c^u}$$

is the share of productive applicants in the search market. Given a worker applies for a firm, where he turns out to be productive, his employment probability from this firm is derived as follows. Suppose that $\tilde{n}$ other *productive* workers also apply for it, which happens with probability $\left(\tilde{x}^{\tilde{n}}e^{-\tilde{x}}\right)/(\tilde{n}!)$. Then the worker is hired with probability $1/(\tilde{n}+1)$. η is the sum of this probability over all $\tilde{n} = 0, 1, 2, ...$ as follows:

$$\begin{aligned}
\eta &= e^{-x} + xe^{-x}\left[\frac{\theta}{2} + 1 - \theta\right] + \frac{x^2e^{-x}}{2}\left[\frac{\theta^2}{3} + \frac{2\theta(1-\theta)}{2} + (1-\theta)^2\right] + ... \\
&\quad + \frac{x^ie^{-x}}{i!}[\theta^i\frac{1}{i+1} + i(1-\theta)\theta^{i-1}\frac{1}{i} + \frac{i!}{2!(i-2)!}(1-\theta)^2\theta^{i-2}\frac{1}{i-1} + ... \\
&\quad + \frac{i!}{j!(i-j)!}(1-\theta)^j\theta^{i-j}\frac{1}{i-j+1} + ... + (1-\theta)^i] + ...
\end{aligned}$$

To see how it works, consider the case $i = 2$ where two other applicants are at the firm, which occurs with probability $\frac{x^2e^{-x}}{2}$ (the third term in the above expression). If both of these applicants appear to be suitable at this firm, which happens with probability θ^2, then the given applicant will receive an offer with probability $\frac{1}{3}$. If one of them is suitable but the other of them is not, which occurs in 2 ways and with probability $\theta(1-\theta)$, then the given applicant will be offered with probability $\frac{1}{2}$. If none of the other applicants happen to be suitable, which happens with probability $(1-\theta)^2$, then the given applicant will be offered with probability one. By induction, the same logic applies to general case with i other applicants (with probability $\frac{x^ie^{-x}}{i!}$): if $j \leq i$ of the other applicants turn out to be suitable, which comes in $\frac{i!}{j!(i-j)!}$ ways and occurs with probability $\theta^j(1-\theta)^{i-j}$, then the given applicant will be offered with probability $\frac{1}{i-j+1}$.

Note that we can simplify the terms,

$$\begin{aligned}
&\theta^i\frac{1}{i+1} + i(1-\theta)\theta^{i-1}\frac{1}{i} + \frac{i!}{2!(i-2)!}(1-\theta)^2\theta^{i-2}\frac{1}{i-1} + \frac{i!}{j!(i-j)!}(1-\theta)^j\theta^{i-j}\frac{1}{i-j+1} + ... + (1-\theta)^i \\
= &\quad \frac{1}{(i+1)\theta}\sum_{j=0}^{i}\frac{(i+1)!}{j!(i+1-j)!}(1-\theta)^j\theta^{i+1-j} \\
= &\quad \frac{1}{(i+1)\theta}\left[\sum_{j=0}^{i+1}\frac{(i+1)!}{j!(i+1-j)!}(1-\theta)^j\theta^{i+1-j} - (1-\theta)^{i+1}\right] \\
= &\quad \frac{1-(1-\theta)^{i+1}}{(i+1)\theta}.
\end{aligned}$$

Using this simplification, we have

$$\eta = \sum_{i=0}^{\infty}\frac{x^ie^{-x}}{i!}\frac{1-(1-\theta)^{i+1}}{(i+1)\theta} = \frac{1}{x\theta}\sum_{i=0}^{\infty}\frac{x^{i+1}e^{-x}(1-(1-\theta)^{i+1})}{(i+1)!}.$$

Setting $h \equiv i+1$, it is further simplified to

$$\begin{aligned}
\eta &= \frac{1}{x\theta}\sum_{h=0}^{\infty}\left[\frac{x^he^{-x}}{h!} - \frac{[x(1-\theta)]^he^{-x}}{h!}\right] = \frac{1}{x\theta}\left[1 - e^{-x\theta}\sum_{h=0}^{\infty}\frac{[x(1-\theta)]^he^{-x(1-\theta)}}{h!}\right] \\
&= \frac{1-e^{-x\theta}}{x\theta} = \eta(\tilde{x}),
\end{aligned}$$

with $\tilde{x} \equiv \theta x$. The standard properties stated in Lemma are immediate from this expression. This completes the proof of Lemma 1. ■

A.2 Proof of Lemma 2

Substituting out w' using equation (2), the objective function of a firm, denoted by $\Pi_s(\tilde{x}')$, can be written as,

$$\Pi_s(\tilde{x}') = \tilde{x}'\eta(\tilde{x}') - \tilde{x}'U^c,$$

where $\tilde{x}' = \tilde{x}(w'|U^c)$ satisfies equation (2). The first-order condition is,

$$\frac{\partial \Pi_s(\tilde{x}')}{\partial \tilde{x}'} = e^{-\tilde{x}'} - U^c = 0.$$

The second order condition can be easily verified. By rearranging this condition using equation (2) one can obtain,

$$w(U^c) = \frac{\tilde{x}'e^{-\tilde{x}'}}{1-e^{-\tilde{x}'}}.$$

In a directed search equilibrium, workers must be indifferent between any of the individual firms. This leads to,

$$w = \frac{\tilde{x}e^{-\tilde{x}}}{1-e^{-\tilde{x}}}, \tag{9}$$

$$U^c = e^{-\tilde{x}}. \tag{10}$$

Hence, given that $w_a = 0$, the equilibrium wage in the search market $w > 0$ is given by equation (9).

We now prove $w_a = 0$ in the PEA, given the search market $w > 0$. Any $w'_a \in (0, w)$ is not profitable so consider a deviation $w'_a \geq w$. Then the deviating firm can hire an assigned productive worker (if any), irrespective of whether the worker gets another offer in search markets. Hence, the best deviation $w'_a = w$ yields the profit,

$$\Pi'_a = \min\left\{\frac{a}{v\rho}, 1\right\}[m + \delta(1-m)](1-w).$$

Substituting $c^c = U^c$ and $c^u = U^u$ using (2) and $w' = w$, we have $\Pi_a(\tilde{x}) > \Pi'_a \iff$

$$mw(1-\eta(\tilde{x})^2) + \delta(1-m)w(1-\delta^2\eta(\tilde{x})^2) > 0,$$

which holds true for any $\tilde{x} \in (0, \infty)$. Thus, $w_a = 0$ is the unique equilibrium wage in the PEA. This completes the proof of Lemma 2. ■

A.3 Proof of Proposition 1

Applying the equilibrium wages in the private market, w, in (9) and the employment probability $\eta(\tilde{x})$ derived in Lemma 1 to (4), we get the equilibrium profit of firms searching in the private market,

$$\Pi_s(\tilde{x}) = 1 - e^{-\tilde{x}} - \tilde{x}e^{-\tilde{x}}. \tag{11}$$

Define $\Gamma \equiv \Pi_s(\tilde{x}) - \Pi_a(\tilde{x})$ for $\tilde{x} \in [0, \infty)$, where by (1) and (10), $\tilde{x} = \tilde{x}(\rho)$ is determined by

$$\frac{e^{-\tilde{x}}}{\tilde{x}} = \frac{v(1-\rho)}{m + (1-m)\delta^2}. \tag{12}$$

This expression shows that $\tilde{x}(\rho)$ is strictly increasing in $\rho \in [0, 1)$ and satisfies $\tilde{x}(0) \equiv \underline{\tilde{x}} \in (0, \infty)$ and $\tilde{x}(\rho) \to \infty$ as $\rho \to 1$.

In what follows, we use the implicit equation $\Gamma = 0$ to show the existence and uniqueness of an equilibrium $\rho \in [0, 1)$. There are two possible cases. Suppose in equilibrium $a > v\rho$. This implies $\rho \in [0, \bar{\rho})$ where $\bar{\rho} \equiv \min\{\frac{a}{v}, 1\}$. Then, using (5) and (11), we can write $\Gamma = \Gamma(\tilde{x})$ where

$$\Gamma(\tilde{x}) = 1 - e^{-\tilde{x}} - \tilde{x}e^{-\tilde{x}} - (m + (1-m)\delta) + \left(m + (1-m)\delta^3\right)\frac{e^{-\tilde{x}}(1-e^{-\tilde{x}})}{\tilde{x}}. \tag{13}$$

Observe that: $\Gamma(0) = -(1-m)\delta(1-\delta^2) < 0$; $\Gamma(\tilde{x}) \to 1-(m+(1-m)\delta) > 0$ as $\tilde{x} \to \infty$. Hence, since $\Gamma(\tilde{x})$ is continuous in $\tilde{x} \in [0,\infty)$, there exists an $\tilde{x}^* \in (0,\infty)$ that satisfies $\Gamma(\tilde{x}^*) = 0$. Observe further that $\frac{\partial \Gamma(\tilde{x})}{\partial \tilde{x}} \mid_{\tilde{x}=\tilde{x}^*} =$

$$
\begin{aligned}
&= \tilde{x}e^{-\tilde{x}} - (m+(1-m)\delta^3)\frac{e^{-\tilde{x}}}{\tilde{x}^2}\left[(\tilde{x}+1)(1-e^{-\tilde{x}}) - \tilde{x}e^{-\tilde{x}}\right] \mid_{\tilde{x}=\tilde{x}^*} \\
&= \frac{\tilde{x}^* e^{-\tilde{x}^*}}{1-e^{-\tilde{x}^*}-\tilde{x}^* e^{-\tilde{x}^*}}\,(m+(1-m)\delta) \\
&- \left(m+(1-m)\delta^3\right)\frac{\tilde{x}^* e^{-\tilde{x}^*}}{1-e^{-\tilde{x}^*}-\tilde{x}^* e^{-\tilde{x}^*}}\left[\frac{e^{-\tilde{x}^*}(1-e^{-\tilde{x}^*})}{\tilde{x}^*} + \frac{1-e^{-\tilde{x}^*}-\tilde{x}^* e^{-\tilde{x}^*}}{\tilde{x}^{*3}}\left[(\tilde{x}^*+1)(1-e^{-\tilde{x}^*}) - \tilde{x}^* e^{-\tilde{x}^*}\right]\right] \\
&> \frac{(m+(1-m)\delta)\,e^{-\tilde{x}^*}}{1-e^{-\tilde{x}^*}-\tilde{x}^* e^{-\tilde{x}^*}}\left[\tilde{x}^* - (1-\frac{1-e^{-\tilde{x}^*}}{\tilde{x}^*})e^{-\tilde{x}^*} - (\frac{1-e^{-\tilde{x}^*}}{\tilde{x}^*} - e^{-\tilde{x}^*})(\tilde{x}^*+1)\frac{1-e^{-\tilde{x}^*}}{\tilde{x}^*}\right] \\
&= \frac{(m+(1-m)\delta)\,e^{-\tilde{x}^*}}{1-e^{-\tilde{x}^*}-\tilde{x}^* e^{-\tilde{x}^*}}\left[\frac{(\tilde{x}^*-(1-e^{-\tilde{x}^*}))(\tilde{x}^*+1-e^{-\tilde{x}^*})}{\tilde{x}^*} - \frac{(1-e^{-\tilde{x}^*}-\tilde{x}^* e^{-\tilde{x}^*})^2}{\tilde{x}^{*2}}\right] \\
&> 0.
\end{aligned}
$$

In the above, we use

$$
\Gamma(\tilde{x}^*) = 0 \Leftrightarrow \tilde{x}^* e^{-\tilde{x}^*} = \frac{\tilde{x}^* e^{-\tilde{x}^*}}{1-e^{-\tilde{x}^*}-\tilde{x}^* e^{-\tilde{x}^*}}\left[(m+(1-m)\delta) - \left(m+(1-m)\delta^3\right)\frac{e^{-\tilde{x}^*}(1-e^{-\tilde{x}^*})}{\tilde{x}^*}\right]
$$

in the second equality, and $\tilde{x}+1-e^{-\tilde{x}} > \frac{1-e^{-\tilde{x}}}{\tilde{x}} - e^{-\tilde{x}}$ and $\tilde{x}-(1-e^{-\tilde{x}}) > 1-e^{-\tilde{x}}-\tilde{x}e^{-\tilde{x}}$ in the last inequality. Since $\Gamma(0) < 0 < \Gamma(\infty)$, $\frac{d\Gamma}{d\tilde{x}} > 0$ at $\tilde{x} = \tilde{x}^*$ implies $\tilde{x}^* \in (0,\infty)$ is unique (that is, $\Gamma(\tilde{x})$ curve cannot cross the line $\Gamma(\tilde{x}) = 0$ more than once).

Finally, notice that the $\tilde{x}^* \in (0,\infty)$ satisfying $\Gamma(\tilde{x}^*) = 0$ determined above does not depend on v, whereas $\underline{\tilde{x}}$ ($\equiv \tilde{x}(0)$) determined by (12) is strictly decreasing in v. Hence, we have

$$
\tilde{x}^* > \underline{\tilde{x}} \Leftrightarrow v > v* \equiv \left(m+(1-m)\delta^2\right)\frac{e^{-\tilde{x}^*}}{\tilde{x}^*}.
$$

On the other hand, denote by $\bar{\tilde{x}}$ the solution of $\tilde{x} = \tilde{x}(\rho)$ to (12) as $\rho \to \bar{\rho}$. If $\frac{a}{v} \geq 1$ then $\bar{\rho} = 1$ and $\bar{\tilde{x}} = \infty$, so $x^* < \bar{\tilde{x}}$. If $\frac{a}{v} < 1$ then $\bar{\rho} = \frac{a}{v} < 1$ and $\bar{\tilde{x}} < \infty$. In this case, $x^* < \bar{\tilde{x}}$ if and only if $v < v^* + a$, since by (12),

$$
\frac{e^{-\bar{\tilde{x}}}}{\bar{\tilde{x}}} - \frac{e^{-\tilde{x}^*}}{\tilde{x}^*} = \frac{1}{m+(1-m)\delta^2}(v(1-\frac{a}{v}) - v^*) = \frac{1}{m+(1-m)\delta^2}(v-a-v^*),
$$

which implies

$$
x^* < \bar{\tilde{x}} \iff \frac{e^{-\bar{\tilde{x}}}}{\bar{\tilde{x}}} < \frac{e^{-x^*}}{x^*} \iff v < v^* + a.
$$

To sum up, we have shown that there exists a unique $\rho \in (0,\bar{\rho})$ that satisfies (12) with $\tilde{x} = \tilde{x}^*$ and $\Pi_s(\tilde{x}^*) = \Pi_a(\tilde{x}^*)$ if and only if $v \in (v^*, v^*+a)$, and $\rho = 0$, satisfying $\Pi_s(\tilde{x}^*) > \Pi_a(\tilde{x}^*)$, if and only if $v \in (0, v^*)$

Suppose next in equilibrium $a \leq v\rho$. This implies $\rho \in [\bar{\rho}, 1)$, where $\bar{\rho} \equiv \min\{\frac{a}{v}, 1\}$, and is possible only when $\frac{a}{v} < 1$. Then, $\Gamma = \Gamma(\rho, \tilde{x})$ where

$$
\Gamma(\rho,\tilde{x}) = 1 - e^{-\tilde{x}} - \tilde{x}e^{-\tilde{x}} - \frac{a}{\rho v}\left[(m+(1-m)\delta) - \left(m+(1-m)\delta^3\right)\frac{e^{-\tilde{x}}(1-e^{-\tilde{x}})}{\tilde{x}}\right], \qquad (14)
$$

where $\tilde{x} = \tilde{x}(\rho)$ is determined by (12) as before. Observe that:

$$
\Gamma(\bar{\rho},\bar{\tilde{x}}) = 1 - e^{-\tilde{x}} - \tilde{x}e^{-\tilde{x}} - \left[(m+(1-m)\delta) - \left(m+(1-m)\delta^3\right)\frac{e^{-\tilde{x}}(1-e^{-\tilde{x}})}{\tilde{x}}\right] \leq 0,
$$

if and only if $v \geq v^* + a$ (see above that $\Gamma(\bar{\rho}, \bar{\tilde{x}}) = \Gamma(\bar{\tilde{x}}) < 0$ for $v \geq v^* + a$); $\Gamma(\rho, \tilde{x}) \to 1 - \frac{a}{v}(m + (1 - m)\delta) > 0$ as $\rho \to 1$. Hence, since $\Gamma(\cdot)$ is continuous in $\rho \in [\bar{\rho}, 1)$, there exists a $\rho^* \in [\bar{\rho}, 1)$ that satisfies $\Gamma(\rho^*, \tilde{x}(\rho^*)) = 0$ if and only if $v \geq v^* + a$. Observe further that

$$\frac{d\Gamma(\cdot)}{d\rho} \mid_{\rho=\rho^*} = \frac{\partial \Gamma(\cdot)}{\partial \rho} + \frac{d\tilde{x}}{d\rho}\frac{\partial \Gamma(\cdot)}{\partial x} \mid_{\rho=\rho^*},$$

where $\frac{\partial \Gamma(\cdot)}{\partial \rho} = \frac{a}{\rho^2 v}\left[m + (1 - m)\delta - (m + (1 - m)\delta^3)\frac{e^{-\tilde{x}}(1 - e^{-\tilde{x}})}{\tilde{x}}\right] > 0$, $\frac{d\tilde{x}}{d\rho} > 0$ (by (12)), and

$$\frac{\partial \Gamma(\cdot)}{\partial \tilde{x}} \mid_{\rho=\rho^*} > \frac{a}{\rho v}\frac{e^{-\tilde{x}}}{1 - e^{-\tilde{x}} - \tilde{x}e^{-\tilde{x}}}\left[\frac{(\tilde{x} - (1 - e^{-\tilde{x}}))(\tilde{x} + 1 - e^{-\tilde{x}})}{\tilde{x}} - \frac{(1 - e^{-\tilde{x}} - \tilde{x}e^{-\tilde{x}})^2}{\tilde{x}}\right] \mid_{\rho=\rho^*} > 0,$$

which follows from exactly the same procedure as developed above to show $\frac{\partial \Gamma(x)}{d\tilde{x}} \mid_{\tilde{x}=\tilde{x}^*} > 0$ in (13). Therefore, $\rho^* \in [\bar{\rho}, 1)$ that satisfies $\Gamma(\rho^*, \tilde{x}(\rho^*)) = 0$ is unique given $v \geq v^* + a$.

Combining with the previous result, we have shown that there exist a unique $\rho \in (0, 1)$ if and only if $v > v^*$, and $\rho = 0$ if and only if $v \leq v^*$. This completes the proof of Proposition 1. ■

A.4 Proof of Corollary 1

The inequality follows immediately by applying $c^c = e^{-\tilde{x}}$ and $c^u = \delta e^{-\tilde{x}}$. This completes the proof of Corollary 1. ■

A.5 Proof of Corollary 2 and 3

In text. ■

A.6 Proof of Proposition 2

As shown in the proof of Proposition 1, the PEA is active for all $a \in (0, 1]$ if and only if $v > v^*$. Hence, it is sufficiently to prove here that the critical value,

$$v* \equiv \left(m + (1 - m)\delta^2\right)\frac{e^{-\tilde{x}^*}}{\tilde{x}^*},$$

is strictly decreasing in m, δ, which is boiled down to prove that $\tilde{x}^*$ is strictly increasing in m, δ when $a > \rho v$. Hence, we concentrate on proving this property below, since the result on parameter a is immediate since a higher a extends the parameter space of the existence of equilibrium with an active PEA, irrespective of the value of v^*.

When $a > \rho v$, with $\Gamma = \Gamma(\tilde{x}^*) = 0$ in (13), we have

$$\begin{aligned}
\frac{\partial \Gamma}{\partial m} \mid_{\tilde{x}=\tilde{x}^*} &= -(1 - \delta) + (1 - \delta^3)\frac{e^{-\tilde{x}}(1 - e^{-\tilde{x}})}{\tilde{x}} \mid_{\tilde{x}=\tilde{x}^*} \\
&= \frac{1 - \delta}{m + (1 - m)\delta^3}\left[-(1 + \delta + \delta^2)(1 - e^{-\tilde{x}^*} - \tilde{x}^* e^{-\tilde{x}^*}) + \delta(1 + \delta)(1 - (1 - \delta)m)\right] \\
&\equiv \frac{1 - \delta}{m + (1 - m)\delta^3}\Upsilon(m).
\end{aligned}$$

In what follows, we show that $\Upsilon(m) < 0$ for all $m \in (0, 1)$. Now, let $y(x) \equiv 1 - e^{-x} - xe^{-x}$. Then, observe that

$$1 - y(x) = e^{-x}(1 + x) > \frac{e^{-x}(1 - e^{-x})}{x}$$

for all $x \in (0, \infty)$. This implies that

$$\begin{aligned}
\Gamma(\tilde{x}^*) &= y(\tilde{x}^*) - (m + (1 - m)\delta) + \left(m + (1 - m)\delta^3\right)\frac{e^{-\tilde{x}^*}(1 - e^{-\tilde{x}^*})}{\tilde{x}^*} \\
&< y(\tilde{x}^*) - (m + (1 - m)\delta) + \left(m + (1 - m)\delta^3\right)(1 - y(\tilde{x}^*)).
\end{aligned}$$

Since $\Gamma(\tilde{x}^*) = 0$, the latter inequality further implies that

$$y(\tilde{x}^*) > \frac{\delta(1+\delta)}{1+\delta+\delta^2}.$$

Applying this relationship into $\Upsilon(m)$, we have:

$$\Upsilon(m) \equiv -(1+\delta+\delta^2)(1-e^{-\tilde{x}^*}-\tilde{x}^*e^{-\tilde{x}^*}) + \delta(1+\delta)(1-(1-\delta)m) < 0$$

for all $m \in (0,1)$. Hence, $\frac{\partial \Gamma}{\partial m} \mid_{\tilde{x}=\tilde{x}^*} < 0$ and, since $\frac{\partial \Gamma}{\partial \tilde{x}} \mid_{\tilde{x}=\tilde{x}^*} > 0$, it follows that $\frac{d\tilde{x}^*}{dm} > 0$. A similar procedure applies to get $\frac{\partial \Gamma}{\partial \delta} \mid_{\tilde{x}=\tilde{x}^*} < 0$ and therefore $\frac{d\tilde{x}^*}{d\delta} > 0$. This completes the proof of Proposition 2. ■

A.7 Proof of Proposition 3

With interview costs, the expected profit of firms in search market is modified to

$$\Pi_s(\tilde{x}) = \tilde{x}\eta(\tilde{x})(1-w) - \frac{\tilde{x}f}{\theta},$$

where $\theta \equiv \frac{m+(1-m)\delta^2}{m+(1-m)\delta}$ is the share of productive applicants in the search market. As before, by considering a deviation w' and its associated queue $\tilde{x}' = \tilde{x}(w'|U^c)$ that satisfies equation (2), we obtain the first-order condition,

$$\frac{\partial \Pi_s(\tilde{x}')}{\partial \tilde{x}'} = e^{-\tilde{x}'} - U^c - \frac{f}{\theta} = 0,$$

which leads to $w = \frac{\tilde{x}(e^{-\tilde{x}} - \frac{f}{\theta})}{1-e^{-\tilde{x}}}$ and $U^c = e^{-\tilde{x}} - \frac{f}{\theta}$. The equilibrium profit in the search market is

$$\Pi_s(\tilde{x}) = 1 - e^{-\tilde{x}} - xe^{-\tilde{x}},$$

where the effective queue is modified to

$$\tilde{x} = \frac{m+(1-m)\delta^2}{v(1-\rho)}(e^{-\tilde{x}} - \frac{f}{\theta}). \tag{15}$$

The equilibrium outcome is identical to the previous one when $f \to 0$. This profit is now compared to the equilibrium profit in the PEA,

$$\Pi_a(\tilde{x}) = \min\left\{\frac{a}{v\rho}, 1\right\}[m(1-c^c\eta(\tilde{x})) + \delta(1-m)(1-c^u\delta\eta(\tilde{x}))] - f,$$

where we now have $c^c = U^c = e^{-\tilde{x}} - \frac{f}{\theta}$ and $c^u = U^u = \delta(e^{-\tilde{x}} - \frac{f}{\theta})$.

Consider the case $a > \rho v$. Now the fixed point condition, $\Gamma \equiv \Pi_s(\tilde{x}) - \Pi_a(\tilde{x}) = 0$, is modified to

$$\Gamma(\tilde{x}) = 1 - e^{-\tilde{x}} - \tilde{x}e^{-\tilde{x}} - (m+(1-m)\delta) + \left(m+(1-m)\delta^3\right)\left(e^{-\tilde{x}} - \frac{f}{\theta}\right)\frac{1-e^{-\tilde{x}}}{\tilde{x}} + f.$$

Define $\bar{f} \equiv \theta(1-m)\delta(1-\delta^2)/(\theta - (m+(1-m)\delta^3)) > 0$. Observe that for $f < \bar{f}$: $\Gamma(0) = -(1-m)\delta(1-\delta^2) + (1 - \frac{m+(1-m)\delta^3}{\theta})f < 0$; $\Gamma(\tilde{x}) \to 1-(m+(1-m)\delta)+f > 0$ as $\tilde{x} \to \infty$. Hence, since $\Gamma(\tilde{x})$ is continuous in $\tilde{x} \in [0,\infty)$, there exists an $\tilde{x}^* \in (0,\infty)$ that satisfies $\Gamma(\tilde{x}^*) = 0$ for $f < \bar{f}$. Hence, we have a continuous function $\tilde{x} = \tilde{x}(f)$. Applying this function to (15) shows that there exists a subset of $f \in (0, \bar{f})$ that guarantees that $\tilde{x} \in (0,\infty)$ and $\rho \in (0,1)$. A similar steps apply to the other case $a \leq \rho v$. This completes the proof of the first claim in Proposition.

We now show the second claim. Consider high enough values of interview costs $f \geq m + (1-m)\delta$ that induces $\Pi_a(\tilde{x}) \leq 0$ for any $\tilde{x} \in (0,\infty)$. Then, since $\frac{m+(1-m)\delta}{\theta} < 1$, a solution $\tilde{x} \in (0,\infty)$ exists to

$$\tilde{x} = \frac{m+(1-m)\delta^2}{v}(e^{-\tilde{x}} - \frac{m+(1-m)\delta}{\theta}).$$

Hence, there exist values of $f \geq m + (1-m)\delta$ that lead to $\Pi_s(\tilde{x}) > 0$ but $\Pi_a(\tilde{x}) \leq 0$, which further leads to $\rho = 0$. This completes the proof of Proposition 3. ■

A.8 Proof of Proposition 4

Given the equilibrium value $\rho \in (0,1)$ (or $\rho = 0$) determined by $\Pi_s(\tilde{x}) = \Pi_a(\tilde{x})$ (or $\Pi_s(\tilde{x}) > \Pi_a(\tilde{x})$) with $\tilde{x} = \tilde{x}(\rho)$, the free entry condition

$$\Pi_s(\tilde{x}) = 1 - e^{-\tilde{x}} - \tilde{x}e^{-\tilde{x}} = K$$

determines a unique value of $v \in (0,\infty)$ (via the determination of $\tilde{x} \in (0,\infty)$ and (12)). Given Proposition 1, this establishes the existence of free entry equilibrium with active search markets. This also implies that there exit high enough values of $K \geq \Pi_a(\tilde{x})$ for any $\tilde{x} \in (0,\infty)$ such that $\Pi_s(\tilde{x}) = K$ and $\rho = 0$. This completes the proof of Proposition 4. ■

A.9 Proof of Proposition 5

Consider the case (6) holds true and the profit of using the PEA is given by (7). Then, for $\frac{a}{v\rho} \geq 1$, we have

$$\Gamma(\tilde{x}) \equiv \Pi_a(\tilde{x}) - \Pi_s(\tilde{x}) = 1 - \frac{e^{-\tilde{x}}(1-e^{-\tilde{x}})}{\tilde{x}} - \left(1 - e^{-\tilde{x}} - \tilde{x}e^{-\tilde{x}}\right) > 0$$

for all $\tilde{x} \in (0,\infty)$. Hence, if $\frac{a}{v} \geq 1$ then $\rho = 1$. For $\frac{a}{v\rho} < 1$, we have

$$\Gamma(\tilde{x}(\rho),\rho) \equiv \Pi_a(\tilde{x}) - \Pi_s(\tilde{x}) = \frac{a}{v\rho}\left(1 - \frac{e^{-\tilde{x}}(1-e^{-\tilde{x}})}{\tilde{x}}\right) - \left(1 - e^{-\tilde{x}} - \tilde{x}e^{-\tilde{x}}\right),$$

which satisfies: $\Gamma(\tilde{x}(\bar{\rho}),\bar{\rho}) = 1 - \frac{e^{-\tilde{x}}(1-e^{-\tilde{x}})}{\tilde{x}} - \left(1 - e^{-\tilde{x}} - \tilde{x}e^{-\tilde{x}}\right) > 0$ with $\bar{\rho} = \frac{a}{v} < 1$; $\Gamma(\tilde{x}(\bar{\rho}),\bar{\rho}) \to \frac{a}{v} - 1 < 0$ as $\rho \to 1$. Hence, if $\frac{a}{v} < 1$ then $\rho \in (\bar{\rho}, 1)$.

Consider next the case (6) does not hold true. Then, the profit to be registered in the PEA is modified to:

$$\Pi_a(\tilde{x}) = m(1 - c^c\eta(\tilde{x})) + \left(\min\{\frac{a}{\rho v}, 1\} - m\right)\delta(1 - c^u\delta\eta(\tilde{x})).$$

For $\frac{a}{\rho v} \leq 1$, the analysis is identical to the one we offered before, where we have shown that there exists a unique $\rho \in (0,\bar{\rho})$ if and only if $v \in (v^*, v^* + a)$, and $\rho = 0$ if and only if $v \in (0, v^*)$. For $\frac{a}{\rho v} > 1$, we define $\Gamma(\tilde{x},\rho) = \Pi_s - \Pi_a$

$$= 1 - e^{-\tilde{x}} - \tilde{x}e^{-\tilde{x}} - \left[\left(m + (\frac{a}{\rho v} - m)\delta\right) - \left(m + (\frac{a}{\rho v} - m)\delta^3\right)\frac{e^{-\tilde{x}}(1-e^{-\tilde{x}})}{\tilde{x}}\right],$$

where $\tilde{x} = \tilde{x}(\rho)$ is determined by (12) as before. Observe that:

$$\Gamma(\bar{\tilde{x}},\bar{\rho}) = 1 - e^{-\bar{\tilde{x}}} - \bar{\tilde{x}}e^{-\bar{\tilde{x}}} - \left[(m + (1-m)\delta) - \left(m + (1-m)\delta^3\right)\frac{e^{-\bar{\tilde{x}}}(1-e^{-\bar{\tilde{x}}})}{\bar{\tilde{x}}}\right] \leq 0,$$

if and only if $v \geq v^* + a$ (as shown in the proof of Proposition 1); $\Gamma(\tilde{x},\rho) \to 1 - (m + (\frac{a}{v} - m)\delta) > 0$ as $\rho \to 1$. Hence, $\rho \in [\bar{\rho}, 1)$ if and only if $v \geq v^* + a$.

To sum, when (6) does not hold true, we must have $\rho \in [0,1)$ for any parameter values. Therefore, $\rho = 1$ if and only if (6) holds true and $\frac{a}{v} \geq 1$, or equivalently $\rho = 1$ if and only if $\min\{a, m\} \geq v$. This completes the proof of Proposition 5. ■

A.10 Correlated worker types

We can modify the baseline setup to allow for a correlation between ex ante worker type (normal or difficult) and search costs. Suppose for instance that search costs of difficult types are distributed uniformly between $\underline{c} > 0$ and $1 + \underline{c}$. The search-costs distribution of normal types remains the same as before. Then, with the introduction of $\underline{c} > 0$, the effective queue of workers is modified to

$$\tilde{x} = \frac{mc^c + \delta(1-m)\max\{c^u - \underline{c}, 0\}}{v(1-\rho)},$$

and the profit in the PEA is modified to

$$\Pi_a(\tilde{x}) = \min\{\frac{a}{\rho v}, 1\}\left[m(1-e^{-\tilde{x}}\frac{1-e^{-\tilde{x}}}{\tilde{x}}) + \delta(1-m)(1-\max\{\delta e^{-\tilde{x}} - \underline{c}, 0\}\delta\frac{1-e^{-\tilde{x}}}{\tilde{x}})\right].$$

With these modifications, consider

$$\begin{aligned}\Gamma(\tilde{x}) &= \Pi_s(\tilde{x}) - \Pi_a(\tilde{x}) \\ &= 1 - e^{-\tilde{x}} - \tilde{x}e^{-\tilde{x}} - (m + (1-m)\delta) + \left(me^{-\tilde{x}} + (1-m)\delta^2\max\{\delta e^{-\tilde{x}} - \underline{c}, 0\}\right)\frac{(1-e^{-\tilde{x}})}{\tilde{x}}.\end{aligned}$$

Observe that: $\Gamma(0) = -(1-m)\delta(1-\delta\max\{\delta - \underline{c}, 0\}) < 0$; $\Gamma(\tilde{x}) \to 1 - (m + (1-m)\delta) > 0$ as $\tilde{x} \to \infty$. Since $\Gamma(\tilde{x})$ is continuous in $\tilde{x} \in [0, \infty)$, this implies that there exists an $\tilde{x}^* \in (0, \infty)$ that satisfies $\Gamma(\tilde{x}^*) = 0$. Hence, our equilibrium can survive with the introduction of a workers' type correlation with search costs. ■

B Appendix: Tables

Table B.1: **Vacancies: PEA used as search and hiring channel (descriptive statistics)**

	Fraction of vacancies (in %) using PEA as search channel	hiring channel
all vacancies	48.3	17.3
low qualification	60.9	17.7
medium qualification	50.3	20.7
high qualification	31.9	5.7
occupation specific experience	47.8	16.4
no occupation specific experience	48.7	18.1
permanent	46.3	14.6
temporary	51.2	21.2
full-time	48.2	15.9
part-time	47.4	23.8
weekend-work	50.6	16.8
no weekend-work	48.4	17.9
firm size (1 - 19)	53.1	22.7
firm size (20 - 49)	46.6	18.6
firm size (50 - 199)	50.2	20.2
firm size (200 - 499)	46.3	14.6
firm size (500 +)	43.8	9.6

Source: German Job Vacancy Survey 2005-2008.
Weighted averages using sampling weights.

Table B.2: **Differences in the fraction of suitable workers for different subgroups**

	Differences in the fraction of suitable workers			
	full sample		restricted sample	
	(1)	(2)	(3)	(4)
low qualification	-0.0424	(0.0298)	-0.0199	(0.0401)
medium qualification	-0.0577**	(0.0095)	-0.0300*	(0.0128)
high qualification	-0.0180	(0.0175)	0.0043	(0.0223)
occupation specific exp. (yes)	-0.0460**	(0.0116)	-0.0323*	(0.0157)
occupation specific exp. (no)	-0.0496**	(0.0114)	-0.0115	(0.0151)
permanent	-0.0737**	(0.0112)	-0.0647**	(0.0151)
temporary	-0.0211*	(0.0121)	0.0196	(0.0158)
full-time	-0.0527**	(0.0091)	-0.0275*	(0.0124)
part-time	-0.0255	(0.0193)	-0.0016	(0.0232)
weekend-work (yes)	-0.0918**	(0.0228)	-0.0810**	(0.0293)
weekend-work (no)	-0.0447**	(0.0098)	-0.0175	(0.0130)
firm size (1 - 19)	-0.0770**	(0.0159)	-0.0391*	(0.0224)
firm size (20 - 49)	-0.0676**	(0.0173)	-0.0447*	(0.0237)
firm size (50 - 199)	-0.0499**	(0.0162)	-0.0420*	(0.0205)
firm size (200 - 499)	-0.0137	(0.0216)	0.0077	(0.0277)
firm size (500+)	0.0506	(0.0212)	0.0831	(0.0271)

Source: German Job Vacancy Survey 2005-2008.
Robust standard errors in brackets. ** indicates $p < 0.01$; * $p < 0.05$.

Table B.3: **Fraction of suitable applicants: External validity**

	OLS-Regressions: Suitable applicants (log)	
	full sample	restricted sample
	(1)	(2)
PEA search channel	-0.0416**	-0.0457**
	(0.0090)	(0.0114)
number of applicants (log)	0.5173**	0.5337**
	(0.0057)	(0.0071)
low qualification	-0.0055	-0.0075
	(0.0181)	(0.0230)
high qualification	-0.0130	0.0008
	(0.0150)	(0.0185)
occupation specific experience	-0.0549**	-0.0570**
	(0.0090)	(0.0112)
permanent	-0.0282**	-0.0273*
	(0.0094)	(0.0119)
full-time	-0.0332**	-0.0213
	(0.0126)	(0.0152)
weekend-work	0.0095	0.0195
	(0.0146)	(0.0176)
firm size (log)	0.0326**	0.0284**
	(0.0034)	(0.0042)
"financial constraints"	0.0069	0.0035
	(0.0168)	(0.0212)
"low sales"	0.0152	0.0085
	(0.0125)	(0.0159)
"skilled labor shortage"	-0.1699**	-0.1699**
	(0.0154)	(0.0229)
region-, occup.-, ind.-FE	yes	yes
R^2	0.6183	0.6442
N	12,792	8,106

Source: German Job Vacancy Survey 2005-2008.
Robust standard errors in brackets. ** indicates $p < 0.01$; * $p < 0.05$.

Table B.4: **Wage difference between registered and unregistered jobs for different sub-groups**

	OLS-Regressions			
	PEA search channel		PEA hiring channel	
	(1)	(2)	(3)	(4)
	full sample			
low qualification	-0.0134	(0.0222)	-0.0018	(0.0236)
medium qualification	-0.0333**	(0.0083)	-0.0203	(0.0109)
high qualification	-0.0416*	(0.0195)	-0.0288	(0.0302)
occupation specific exp. (yes)	-0.0346*	(0.0149)	-0.0464*	(0.0210)
occupation specific exp. (no)	-0.0315**	(0.0082)	-0.0173	(0.0109)
permanent	-0.0397**	(0.0093)	-0.0227	(0.0136)
temporary	-0.0178	(0.0119)	-0.0087	(0.0131)
full-time	-0.0322**	(0.0077)	-0.0221*	(0.0101)
part-time	-0.0541**	(0.0200)	0.0043	(0.0258)
weekend-work (yes)	-0.0170	(0.0163)	0.0272	(0.0209)
weekend-work (no)	-0.0337**	(0.0080)	-0.0307**	(0.0107)
firm size (1 - 19)	-0.0343*	(0.0158)	-0.0349	(0.0211)
firm size (20 - 49)	-0.0435**	(0.0138)	-0.0075	(0.0172)
firm size (50 - 199)	-0.0229	(0.0136)	-0.0289	(0.0186)
firm size (200 - 499)	-0.0412	(0.0473)	-0.0179	(0.0721)
firm size (500+)	-0.0161	(0.0407)	0.0706	(0.0755)
	restricted sample			
low qualification	0.0611	(0.0569)	-0.0061	(0.0588)
medium qualification	-0.0505**	(0.0131)	-0.0273	(0.0181)
high qualification	-0.0261	(0.0331)	-0.0953	(0.0514)
occupation specific exp. (yes)	-0.0272	(0.0264)	-0.0644	(0.0394)
occupation specific exp. (no)	-0.0472**	(0.0129)	-0.0268	(0.0176)
permanent	-0.0395**	(0.0146)	-0.0421	(0.0236)
temporary	-0.0238	(0.0210)	-0.0174	(0.0235)
full-time	-0.0394**	(0.0121)	-0.0390*	(0.0172)
part-time	-0.1120**	(0.0292)	0.0608	(0.0340)
weekend-work (yes)	-0.0504	(0.0319)	0.0604	(0.0401)
weekend-work (no)	-0.0412**	(0.0125)	-0.0485**	(0.0181)
firm size (1 - 19)	-0.0349	(0.0290)	-0.0561	(0.0436)
firm size (20 - 49)	-0.0731**	(0.0255)	-0.0021	(0.0277)
firm size (50 - 199)	-0.0506*	(0.0208)	-0.0149	(0.0300)
firm size (200 - 499)	-0.0583	(0.2339)	-0.0780	(0.3532)
firm size (500+)	0.0956	(0.1521)	0.1360	(0.3286)

Source: German Job Vacancy Survey 2014, restricted sample.
Robust standard errors in brackets. ** indicates $p < 0.01$; * $p < 0.05$.
NA: The number of observations was too small.

Table B.5: **Recruiting difficulties due to "high wage demands" for different subgroups**

	Recruiting difficulties due to "high wage demands"			
	Marginal effects (probit)		Marginal effects (probit)	
	PEA search channel		PEA hiring channel	
	(1)	(2)	(3)	(4)
	full sample			
low qualification	0.0926**	(0.0323)	-0.0278	(0.0361)
medium qualification	0.0452**	(0.0057)	-0.0049	(0.0065)
high qualification	0.0435**	(0.0136)	-0.0207	(0.0197)
occupation specific exp. (yes)	0.0364**	(0.0076)	-0.0002	(0.0092)
occupation specific exp. (no)	0.0578**	(0.0070)	-0.0149	(0.0082)
permanent	0.0529**	(0.0076)	0.0017	(0.0092)
temporary	0.0431**	(0.0075)	-0.0151	(0.0088)
full-time	0.0420**	(0.0053)	-0.0086	(0.0063)
part-time	0.0722**	(0.0159)	-0.0132	(0.0184)
weekend-work (yes)	0.0927**	(0.0173)	-0.0406*	(0.0207)
weekend-work (no)	0.0382**	(0.0050)	-0.0054	(0.0059)
firm size (1 - 19)	0.0947**	(0.0217)	-0.0079	(0.0221)
firm size (20 - 49)	0.0705**	(0.0127)	-0.0415**	(0.0154)
firm size (50 - 199)	0.0558**	(0.0140)	-0.0055	(0.0178)
firm size (200 - 499)	0.1534**	(0.0465)	0.1462*	(0.0638)
firm size (500+)	0.0330	(0.0349)	0.0180	(0.0556)
	restricted sample			
low qualification	0.1873**	(0.0596)	-1.1490*	(0.0732)
medium qualification	0.0501**	(0.0077)	-0.0069	(0.0088)
high qualification	0.0491**	(0.0229)	-0.0669*	(0.0363)
occupation specific exp. (yes)	0.0578**	(0.0112)	-0.0158	(0.0134)
occupation specific exp. (no)	0.0582**	(0.0096)	-0.0156	(0.0113)
permanent	0.0747**	(0.0121)	-0.0096	(0.0147)
temporary	0.0519**	(0.0110)	-0.0240*	(0.0129)
full-time	0.0440**	(0.0071)	-0.0054	(0.0083)
part-time	0.0811**	(0.0227)	-0.0601	(0.0311)
weekend-work (yes)	0.1726**	(0.0303)	-0.1467**	(0.0400)
weekend-work (no)	0.0390**	(0.0069)	-0.0069	(0.0080)
firm size (1 - 19)	0.0947**	(0.0217)	-0.0079	(0.0221)
firm size (20 - 49)	0.1211**	(0.0207)	-0.0635*	(0.0289)
firm size (50 - 199)	0.1407**	(0.0265)	-0.0869*	(0.0372)
firm size (200 - 499)	NA	NA	NA	NA
firm size (500+)	NA	NA	NA	NA

Source: German Job Vacancy Survey 2005-2010.
Robust standard errors in brackets. ** indicates $p < 0.01$; * $p < 0.05$.
NA: The number of observations was too small.

Table B.6: **Worker characteristics (descriptive statistics)**

	Characteristics of non-employed actively searching individuals		
	all	via the PEA	without the PEA
number of search channels	2.8	3.2	1.9
PEA (search channel)	70.9%	100%	0%
Job ads (search channel)	73.7%	75.4%	69.8%
Network (search channel)	64.2%	65.6%	60.6%
Internet (search channel)	50.5%	53.2%	43.9%
Speculative appl. (s.ch.)	25.5%	28.2%	19.0%
registered unemployed	85.9%	89.7%	64.3%
female	52.4%	48.7%	61.4%
age	38.6 yrs	38.3 yrs	39.3 yrs
work experience (full-time)	10.6 yrs	10.7 yrs	10.2 yrs
work experience (part-time)	1.7 yrs	1.7 yrs	1.8 yrs
unemployment experience	3.6 yrs	3.7 yrs	3.2 yrs
inadequate education	3.3%	3.6%	2.9%
general elementary	18.5%	18.3%	18.8%
middle vocational	53.7%	54.3%	52.3%
vocational & high school	3.8%	3.7%	4.2%
higher vocational	5.7%	6.1%	4.7%
higher education	10.7%	10.0%	12.3%

Source: German Job Vacancy Survey 2005-2007.
Weighted averages using sampling weights.