# Labor Market Tightness and Hiring Outcomes: Evidence from Job Application Data<sup>\*</sup>

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#### Abstract

This study explores a novel measure of labor market tightness to examine how tightness affects hiring outcomes of firms. The analysis uses detailed matched firm-vacancy-worker data from Austria, covering a significant portion of the labor market in recent years. To quantify the supply of jobseekers, I exploit vacancylevel variation in the number of job applications, inferred from referrals made by the public employment service. To address application endogeneity, I instrument the number of referral applications with the number of unemployed workers resulting from mass layoffs in the months prior to vacancy posting. The estimation results show that a higher number of suitable applicants leads to both shorter vacancy filling duration and higher sectoral match quality of eventual hires. Consistent with the rise in match quality, I also find positive effects on starting wages and job duration of hired workers. Moreover, labor market tightness attenuates firm segregation by gender and nationality of workers. When the supply of qualified applicants decreases, firms with higher shares of male workers are more likely to hire female workers, and firms with higher shares of Austrian workers are more likely to hire workers of foreign nationality.

#### **JEL Classification:** J22, J62, J63, J71

**Keywords:** Labor market tightness, vacancies, recruitment, worker-firm match quality, worker segregation

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### 1 Introduction

Worker shortages have recently garnered increased attention from both academics and policymakers. Particularly in English-speaking countries, the number of unfilled vacancies has risen substantially across various sectors (Duval et al., 2022; Causa et al., 2022). Many countries are expected to face even stronger labor supply shortages in the upcoming decades: the retirement of the baby boomer generation in the years ahead is anticipated to substantially reduce the overall workforce. If the demand for labor exceeds the available supply of qualified workers, employers will find it increasingly challenging to fill job vacancies. As not all sectors of the economy are equally affected by these shortages, worker movements across sectors and occupations will play a central role in the necessary adjustment of the labor market, requiring higher flexibility and more retraining of workers.

Stronger mobility can also lead to more mismatches between workers and firms. Despite retraining efforts, some hired workers might still not meet the necessary skill requirements for a given job. This has severe implications for both workers and firms. Firms may become less productive and could be forced to layoff some workers again. Mismatched workers who are eventually laid off may struggle to reintegrate into the labor market. In contrast, higher mobility could benefit those workers who are qualified but face entry barriers due to labor market discrimination. If, for instance, the gender of applicants plays a major role in the firm's hiring decisions (Card et al., 2021; Bamieh and Ziegler, 2023), women find it more difficult to be hired for jobs that are typically taken up by men, and vice versa. Higher labor market tightness, i.e. a lower number of suitable job applicants per vacancy, might weaken the impact of gender preferences in the hiring process. Similarly, workers of foreign nationality could benefit from worker shortages if employers discriminate against foreigners in loose labor markets.

This study explores a novel measure of labor market tightness and examines its relationship with various hiring outcomes. The analysis uses detailed matched firmvacancy-worker data from Austria, covering a large share of the labor market in recent years. To quantify the demand for vacant jobs, I exploit vacancy-level variation in the number of suitable job seekers, inferred from job referrals to unemployed workers. Because the extent of applications might be related to unobserved vacancy characteristics, I propose an instrumental variable strategy that leverages variation in labor market tightness caused by mass layoffs. Specifically, I use the number of unemployed workers resulting from mass layoffs in the months prior to vacancy posting as an instrument for the number of applications. This unexpected and large sector- and region-specific influx of jobseekers creates a positive supply shock for recruiting firms, thereby reducing labor market tightness. To measure the extent of mismatch between workers and firms, I focus on worker-level data on previous labor market experience. By examining additional worker characteristics such as gender and nationality, I also test whether higher tightness can improve hiring outcomes for groups that likely suffer from employer discrimination.

The empirical analysis combines micro-level administrative data on job postings and job applications from the Austrian public employment service (AMS) with worker spells from the Austrian social security administration. A comparison with data from a representative sample of Austrian firms shows that AMS covers about 50-60 percent of all vacancies. Importantly, the database includes many vacancy characteristics relevant to this analysis such as occupation, sector, and the time until a vacancy is filled (Mueller et al., 2024; Bamieh and Ziegler, 2022). To assist in the job search process, the Austrian employment service mediates vacancies to jobseekers. Using data on these referrals, I construct proxies of the vacancy-specific supply of workers. To study hiring outcomes of posted vacancies, I link worker and vacancy data at the firm level, which is possible for most firms. Data on previous employment spells of hired workers allow me to gauge the workers' suitability for the filled vacancies.

If recruiters do not find applicants with the desired worker profile right away, they may accept a worse fit, or keep the job vacant and continue searching. As a result, tighter labor markets may lead to a higher degree of mismatch but also longer vacancy filling durations. To examine this trade-off between vacancy duration and worker match, I propose a stylized two-period model, in which firms can decide whether to delay hiring. If the share of suitable applicants decreases, firms may lengthen or even shorten their search, depending on the productivity loss they face with mismatched workers and the costs of keeping a position unfilled. This will lead to different degrees of worker mismatches because longer search periods can partly attenuate the extent of mismatches. Building upon these implications, the empirical analysis examines how changes in the supply of workers affect both vacancy duration and hiring outcomes. To construct a proxy for the supply of suitable applicants, I compare the firm's sector (at the 4-digit NACE level) to the sector in which referred job seekers previously worked. Based on sector-to-sector transitions observed in earlier years, the referrals are weighted by the transition probabilities from the jobseeker's previous sector.

Estimation results show that a higher number of suitable applicants leads to both shorter vacancy filling durations and better sectoral matches. When vacancies receive more applications, hired workers are also paid higher wages and stay longer in the job, which is consistent with the observed increase in worker-firm match quality. Effect sizes remain similar when excluding vacancies for which a referred jobseeker was hired. Moreover, I find that increasing labor market tightness attenuates firm segregation by gender and nationality of workers. If the supply of suitable workers decreases, firms with higher shares of male workers are more likely to hire female workers, and firms with higher shares of Austrian workers are more likely to hire workers of foreign nationality.

The role of labor market tightness for firms and workers has been a longstanding question in labor economics, but little empirical evidence exists at the vacancy level. Macroeconomic research studying job creation and wage setting usually exploits time series data of aggregated labor market tightness at the national or state level (Shimer, 2005; Domash and Summers, 2022). Recently, several papers in this literature have started to explore variation at the firm- and worker-level in this context. Davis et al. (2013) analyze hiring behavior on the establishment level using US data from the Job Openings and Labor Turnover Survey (JOLTS). Abraham et al. (2020) use micro data from the Current Population Survey (CPS) to track worker flows across labor market states in the US, which yields a more precise measure of labor market tightness. Another viable data source in this context is online job postings, which have been used by Azar et al. (2020) and Turrell et al. (2021) to study the impact of labor market tightness at the occupation level. Hoeck (2023) draws on linked firm-vacancy-worker data from Denmark to define firm-specific measures based on the occupational composition within firms. A recent study by Klaeui et al. (2024) uses detailed click data from jobseekers and recruiters to study the impact of labor market tightness on occupational mobility.

They find that when the relative supply of suitable applicants for an occupation is scarce, jobseekers are less likely, and recruiters are more likely, to search more broadly. By combining vacancy and job application data with employment spells, I extend the analysis of labor market tightness to examine the impact of vacancy-specific scarcity on realized hiring outcomes.

Numerous studies document the prevalence of mismatches in the labor market and highlight their negative consequences for individual workers and the aggregate economy. Mismatches can affect the workers' human capital and limit career advancement. If their level of education does not match the job requirements, workers often suffer substantial income losses (Nordin et al., 2010; Altonji et al., 2016). Macroeconomic research links occupational and sectoral mismatches to decreases in productivity (Patterson et al., 2016) and higher unemployment (Şahin et al., 2014).

This paper also connects to the literature in personnel economics, studying the determinants and consequences of firms' hiring decisions (Over and Schaefer, 2011; Bloom and Van Reenen, 2011). A central aspect in this context is the relationship between labor market tightness and worker compensation. When many firms compete for few workers, employers might increase wage offers to attract qualified job applicants. This relationship also follows from standard search-and-matching models (Pissarides, 2000), as job seekers improve their bargaining position in tighter labor markets. Yet, existing evidence does not suggest a major role of pay adjustments. Using the Austrian vacancy database, Mueller et al. (2024) analyze the connection between vacancy duration and wages. The study finds that vacancies fill faster when starting wages are higher, which is consistent with the hypothesis that firms increase wage offers to reduce vacancy duration. The estimated elasticities are, however, small and contribute little to the overall variation in vacancy filling. Cullen et al. (2024) analyze wage posting data from a large staffing platform and find that many firms do not adjust wage offers when faced with labor shortages. Based on experimental evidence, they conclude that, although higher wages would increase hiring rates, high adjustment costs and low awareness of the potential impact of higher wages prevent wage adjustments in many cases. In other settings, pay equity concerns may also play a role, when firms pay newly recruited workers more than their previous hires (Cullen and Perez-Truglia, 2022).

A central insight of the seminal work by Becker (1957) is that increased competition makes it harder for firms to sustain discriminatory hiring behavior. While this idea was originally formulated for product market competition, a similar argument also applies to hiring competition in the labor market. Exploiting business cycle variation, Biddle and Hamermesh (2013) show that tighter labor markets are associated with smaller gender and racial wage gaps. These differences can also be observed during the hiring stage: when labor markets are tight, race-based discrimination against job applicants is less prevalent (Baert et al., 2015; Doleac and Hansen, 2020). In line with the existing evidence on discriminatory hiring behavior, I find that firm segregation by gender and nationality increases when vacancies receive more applications.

### 2 Theoretical predictions

When labor markets are tight, employers find it more difficult to fill their vacancies. On the one hand, they might postpone hiring until a fitting jobseeker applies for the position. On the other hand, they may lower their expectations and hire applicants with fewer skills or less experience. The firms' decision will depend on the urgency to fill a vacancy, i.e. the costs of leaving it unfilled, and the loss in productivity when a worker without the necessary job requirements is hired.

To examine the trade-off between vacancy duration and worker match, I propose a stylized model of the firm's search process. In every period, firms aiming to fill a vacancy receive one application from a jobseeker. With probability p = Pr(H), the applicant fulfills the required skills and work experience (type H); otherwise the applicant lacks these requirements (type L). If firms receive a suitable application, they will hire the worker, who will yield them payoff Y in each of the remaining periods. If firms receive a low-match application, they can hire the mismatched worker but will endure a relative productivity loss of q each period. Alternatively, they may decide to leave the vacancy unfilled and continue searching in the next period, in which they again receive one application. Figure 1 illustrates the firm's decision tree in a model with two hiring periods.

In this setting, the firm only has to choose once whether they want to hire the worker



Figure 1: Hiring decision tree (two-period model)

or continue searching if they receive a low-match application in the first period. The firm only continues searching if the probability of hiring a high-match worker in the second period is sufficiently high compared to the productivity loss with a low-match worker:

$$pY + (1-p)(1-q)Y \ge 2(1-q)Y$$
$$\Leftrightarrow \quad p \ge 2\frac{(1-q)}{q}$$

The degree of productivity loss might differ a lot between vacancies. The tasks of some jobs might also be done reasonably well by workers without the requested profile, while for others, the requirements are indispensable. As a result, there will be jobs with on average lower worker match quality and shorter vacancy duration and jobs with higher match quality but longer duration.

In this setting, tighter labor markets can be characterized by a lower probability of receiving applications from suitable jobseekers (p). If tightness rises, that is, the probability decreases, some firms will adapt their hiring strategy accordingly:

1. Firms with sufficiently large q do not change their strategy and continue searching in case of a mismatch in the first period. There will be a small decrease in worker match quality as the share drops from  $1 - (1 - p_{old})^2$  to  $1 - (1 - p_{new})^2$ . Moreover, vacancy duration will increase due to a higher likelihood of mismatch in the first period.

- 2. Firms with sufficiently low q do not change their strategy either and always stop after the first period. This results in a medium decrease in worker match quality as the share drops from  $p_{old}$  to  $p_{new}$ . Yet, the vacancy filling duration remains unchanged.
- 3. Firms with medium q might now decide to stop after the first period although they opted to continue in a looser labor market. This leads to a strong decrease in worker match quality and the share drops from  $1 - (1 - p_{old})^2$  to  $p_{new}$ . In this case, vacancy filling duration decreases.

This shows that the impact of higher labor market tightness on vacancy filling duration and worker match quality depends on the firm's costs of hiring low-match workers. If changes in the supply of qualified workers affect the hiring strategy of many firms, the extent of mismatch will be amplified but vacancies tend to be filled faster. The model can be extended in multiple ways without changing its main implications. Allowing for worker layoffs once a better matching jobseeker applies increases the hiring of low-match workers as the associated costs decrease. Similarly, introducing a discount factor for future payoffs increases low-match hires because unfilled vacancies become relatively more costly. In both cases, the predicted effect on vacancy duration and match quality will remain qualitatively the same.

### 3 Setting and data

#### 3.1 Vacancies

The empirical analysis combines data on vacancies, job referrals and employment spells in the Austrian labor market. The vacancy database covers the universe of job postings reported to the Austrian public employment service (AMS), which hosts the largest job board in Austria. In recent years, the job board covers about 50-60 percent of all vacancies in Austria.<sup>1</sup> Contrary to most private job boards, the public employment

<sup>&</sup>lt;sup>1</sup>Statistics Austria conducts an annual vacancy survey on the firm level, which allows to back out the AMS coverage rate.

service actively manages its vacancy database and stays in contact with advertising employers. Most importantly, they regularly check back with employers whether and when vacancies are filled. The vacancy database records a vacancy's posting date as well as its expected job start date and its removal date. In my analysis, I define vacancy duration as the days between vacancy posting and vacancy removal. Moreover, I will control for the days between vacancy entry and expected job start date.<sup>2</sup> Importantly, the database also links each vacancy to the respective firm and occupation. The public employment service uses a detailed 6-digit classification of occupations, which allows to distinguish occupations on a fine-grained level.<sup>3</sup>

#### 3.2 Hiring outcomes

To examine hiring outcomes, I link the vacancies to records from the Austrian social security database.<sup>4</sup> In addition to basic worker characteristics (gender, nationality, age), the database records all employment spells which are subject to social security contributions as well as the corresponding earnings. The dataset also covers firm characteristics, which include the sector of firms at the 4-digit NACE level ( $\approx 600$  sectors).

The combination of these data allows me to construct several measures of a hired worker's match quality. The first measure compares the firm's sector to the sector in which the hired worker was last employed. Instead of a sector match indicator, I estimate sector-to-sector transitions in the Austrian labor market (observed in the year before the start of the sample period) to obtain more precision in the measurement of match quality. For each sector k, I compute the share of worker transitions from all sectors l, where matches of the most common sector transition are normalized to 1:

$$M_{kl} = Pr(\text{Sector} = k | \text{Prev. sector} = l) / max_l \{ Pr(\text{Sector} = k | \text{Prev. sector} = l) \}$$

If, for instance, 80 percent of workers hired in sector A worked in the same sector before and the remaining 20 percent worked in sector B, the match quality of those

 $<sup>^{2}</sup>$ Mueller et al. (2024) provide an extensive discussion of different measures of vacancy duration in the AMS vacancy database.

 $<sup>^{3}</sup>$ The corresponding occupation dictionary, also providing the respective ISCO codes, is available at https://www.ams.at/bis (in German).

 $<sup>^{4}</sup>$ Zweimüller et al. (2009) provide a comprehensive description of the data source.

coming from A is 80/80 = 1, whereas the match quality of those coming from B is 20/80 = 0.25. For all remaining sectors, the value is 0. As a result, this measure also differentiates match quality when no same-sector match exists. Because the sector classification distinguishes about 600 sectors, many cross-sector transitions are common and should not be classified as mismatches.<sup>5</sup> To quantify sector-specific work experience, I compute the length of previous employment spells in the last five years and multiply this duration with the match quality measure  $M_{kl}$ , thereby putting more weight on work experience in better-matching sectors. Next to the workers' employment history, I use job duration and daily earnings in the first year of the new hire as proxies for worker match quality. Workers who match the advertised position should be more productive, which should lead to higher wages and longer job duration.

#### 3.3 Demand for vacancies

Active vacancy listings are accessible through the AMS online job board, which does not require prior registration. Moreover, AMS caseworkers, who support the job search of unemployed workers, use the database to refer them to suitable vacancies. In my analysis, I use data on the number and type of these referrals to proxy the demand for each vacancy. When jobseekers register as unemployed, the assigned caseworker typically schedules an in-person meeting within the first 10 days. Registered jobseekers can also use their AMS online account to provide additional information about themselves and create an individual search profile. Screening the worker profiles and the stock of vacancies, caseworkers ask jobseekers to apply to suitable vacancies. Whether a job is deemed suitable depends on a set of formal rules. These criteria include the job's education requirements, physical requirements, pay difference to prior job, distance to work and working hours.<sup>6</sup>

Despite these rules, referral decisions depend to some extent on the individual assessment of caseworkers. While some caseworkers choose from a narrow set of vacancies, others refer jobseekers to a wider range of jobs. To adjust for these differences, I weight

<sup>&</sup>lt;sup>5</sup>An example of related groups are the sectors *I56.1* - *Restaurants and mobile food service activities* and *I56.2* - *Event catering and other food service activities*.

 $<sup>^6{\</sup>rm The}$  public employment service describes the criteria on their website: www.ams.at/arbeitsuchende (in German).

the worker referrals by their sector match quality, comparing again the vacancy's sector with the sector of the jobseeker's previous employment. As for the match quality of hired workers, I weight each job referral  $r_i$  by its match quality measure  $M_{kl}$  as defined above. The match-adjusted number of referrals  $ref_i$  of vacancy i is then given by

$$ref_i = \sum_{r=1}^{n_{r_i}} M_{kl}(r_i),$$

where  $n_{r_i}$  is the vacancy's unadjusted number of referrals. In the following, I will use this measure to proxy the vacancy-specific supply of suitable workers.

#### 3.4 Estimation sample

The estimation sample consists of filled vacancies for regular, permanent employment posted on the AMS job board in the years 2002 to 2019. As in Halla et al. (2020), I exclude sectors with strong seasonality in hiring and layoffs (hospitality, construction and agriculture) to avoid confounding seasonal employment changes with mass layoffs in the IV analysis. For most vacancies, employment spells of hired jobseekers cannot be directly linked on the worker level. Instead, I exploit firm linkages between the vacancy database and the social security records, which are available for a subset of firms in the sample. To match workers and filled vacancies, I assign the closest firm hire within a 90-day window around the date on which a vacancy was removed. If multiple workers are hired on the closest date, one of the matches is randomly chosen. With this procedure, I can match workers for 50 percent of vacancies.

If vacancies are filled through mediation by AMS following a jobseeker referral (about 20 percent of vacancies), anonymized person identifiers are available, which allow direct linkages of workers and vacancies. While mediated hires are a selected sub-sample of all recruited workers, this provides an opportunity to assess the performance of the described matching procedure. In Section 4.4, I will use the subsample to learn how matching vacancies and hires at the firm level affects the estimation results. The final sample comprises about 1.2 million vacancy observations for which hiring outcomes are observed. Table 1 shows summary statistics for the key variables in the analysis.

The upper part of the table provides statistics on jobseeker referrals and vacancy duration. The average number of sector-weighted referrals in the first week  $(ref_i)$  is 1.21

	Mean	Std. Dev.	Median
# referrals	1.13	1.91	0.39
Vacancy duration	50.95	46.55	36.00
Days until. exp. job start	16.48	30.27	4.00
Hiring outcomes:	0.05	0.40	0.00
Sector match (direct)	0.25	0.43	0.00
Sector match (propensity)	0.32	0.41	0.08
Sector-weighted exp. $(in days)$	243.09	409.23	52.43
Daily earnings (in EUR)	68.00	33.28	63.35
Job duration (in days)	404.45	418.63	207.00
Female hire	0.46	0.50	0.00
Foreign hire	0.23	0.42	0.00
<u>Firm sector</u> :			
Retail/Wholesale	0.21	0.41	0.00
Admin./support service	0.26	0.44	0.00
Manufacturing	0.19	0.39	0.00
Other sector	0.34	0.47	0.00
Vacancy observations		1,181,744	

 Table 1: Descriptive statistics

and there are relatively large differences between the vacancies (SD = 1.9). Employers need on average 50 days to fill vacancies, and the mean duration between posting date and expected job start date is about two weeks. Figure 2 plots the relative frequencies of filling duration in weeks, showing that most vacancies are filled within the first month. Around 15 percent of vacancies take longer than three months to fill.

The middle part of Table 1 summarizes the hiring outcomes used in the analysis. Among the matched hires, a fourth of workers were previously employed in the same sector (on the NACE 4-digit level). The average weighted match quality  $(M_{kl})$ , which also takes into account cross-sector worker flows, is somewhat higher (30 percent). Considering their preceding five years of employment, hired workers have on average 8



Figure 2: Histogram of vacancy duration

months of sector-weighted work experience. In addition to sector matches, the starting wage and job tenure will serve as proxies for match quality between hires and vacancies. On average, new jobs last about a year and pay 70 Euros per day. To estimate effects on worker segregation between firms, I will further consider the gender and nationality of hires. In the estimation sample, every second worker is female and about 75 percent are Austrian nationals.

### 4 Analysis

#### 4.1 Estimation approach

As shown by the theoretical outline in Section 2, changes in the supply of suitable job applicants may affect both vacancy duration and match quality between hires and firms. Fewer applications of fitting jobseekers should lead to a higher number of mismatches, but firms may choose to delay hiring to alleviate the negative impact on match quality. In this section, I leverage the firm-vacancy-worker data to study the relationship between vacancy duration and the supply of suitable applicants, using mass layoffs just before vacancy posting as an instrument for the number of referral applications. Moreover, I estimate the relationship between the hiring outcomes discussed in the previous section and the extent of applications to examine changes in match quality between workers and firms.

Much of the correlation between vacancy filling and worker supply might be driven by differences in vacancy types. If hiring for specific jobs requires a thorough assessment of applicants, recruiters will need some time to fill these vacancies, even when plenty of qualified jobseekers apply. Also the degree of sectoral mismatch differs substantially between jobs. While in very specialized sectors, cross-sector hires may require substantial retraining efforts, transitions between other sectors can be more seamless. Two other potentially relevant determinants of hiring success are the timing of a vacancy posting and the job location. The number of unemployed workers varies over the year and there exist longer run differences due to business cycle variations and secular trends in the supply of workers. This can, for instance, be caused by changes in the demographic composition of the workforce. Spatial differences in the number of suitable jobseekers likely affect vacancy filling as well. Factors such as family ties and housing market constraints often discourage geographic mobility of workers and limit the extent of broader job searches.

The detailed job characteristics in the Austrian vacancy database enable me to account for many of these factors. To quantify the impact of the supply of applicants on the duration of vacancy filling and hiring outcomes, I estimate regressions for each outcome  $y_i$  of the following form:

$$y_i = \gamma \, ref_i + \beta \, d_i + \psi_k + \kappa_o + \lambda_t + \varepsilon_i \tag{1}$$

As outlined in Section 3.3, variable  $ref_i$  is the sector-weighted number of referred jobseekers to vacancy *i* in the first week of posting.  $\psi_k$ ,  $\kappa_o$ ,  $\lambda_t$  denote the firm, occupation and posting-month fixed-effects, respectively. Variable  $d_i$  refers to the days between vacancy posting and expected job start, and  $\varepsilon_i$  is the error term.

Firm fixed-effects can account for differences in the firms' hiring practices as well as differences between sectors and regional labor markets. The fine-grained distinction of occupations in the vacancy database allows to remove occupation-specific links between the extent of job referrals and the search process. Finally, posting month indicators can account for job market seasonality and longer-run time trends. Next to the set of fixed effects, I control for the duration between vacancy posting date and expected job start date. If the job is expected to start soon, vacancy filling is more urgent, which should affect both filling duration and hiring outcomes.

Because the number of referrals may still be affected by other unobserved factors that drive vacancy duration and hiring results, I propose an instrumental variable (IV) approach exploiting variation caused by worker mass layoffs. Specifically, the number of laid-off workers by sector and district in the months prior to vacancy posting will serve as an instrument for the number of referrals per vacancy. When firms shut down or need to lay off a large share of their workforce, other firms operating in the same sector and location should experience a surge in applications for their available vacancies. Using the layoff events as an instrument, the IV approach allows to isolate the variation in referral applications driven by this labor market shock. As in Halla et al. (2020), I will follow the definition of mass layoffs used by the Austrian public employment service, which requires a minimum number of dismissals relative to the firms' initial workforce.<sup>7</sup> The underlying identification assumption requires that mass layoffs do not affect hiring results (conditional on firm and occupation fixed effects), neither directly nor indirectly through correlations with other unobserved determinants of the hiring process.

<sup>&</sup>lt;sup>7</sup>Based on worker flows in the Austrian social security data, it is possible to distinguish between plant closures and plant mergers (Fink et al., 2010).



Figure 3: Vacancy filling duration and number of referrals

### 4.2 Vacancy duration and hiring outcomes

Figure 3 plots the raw relation between the number of jobseeker referrals and vacancy filling time, showing that vacancies with a low number of referrals need many more days to find a hire. In particular, vacancies that do not receive any referral applications are associated with long vacancy durations. For vacancies with referrals, the average filling duration monotonically declines and eventually flattens out. Comparing vacancies without referrals to those with six or more, the vacancy duration drops by 40 percent, which corresponds to almost a one month difference. If the job start of hires is delayed by the same time, this would mean substantial economic costs for affected employers.

To isolate the impact of applications from other correlated effects, I next estimate equation (1) and instrument the number of referrals with the number of sector- and region-specific mass layoffs in the months before job posting. Table 2 summarizes the estimation results for various hiring outcomes. First-stage estimates of the relation between mass layoffs and applications are provided in the upper panel. To capture log-changes in layoffs and also accommodate zero values, I use the inverse hyperbolic sine of layoffs as instrument (see, e.g., Card et al., 2022). The table shows results for instruments that take into account layoffs in up to three months before the vacancies were posted. A longer time span will cover more potential applicants but some of the earlier layoffs may not be available anymore because they already found work earlier. The first-stage estimates indicate that the impact is similar with all three instruments. There exists a small but statistically strong relation between the number of laid-off workers and the number of referral applications: a one standard deviation (SD = 1.5) increase in the instrument is associated with about 0.1 additional applications, which yields large F-statistics on the instruments.

The lower panel of Table 2 provides OLS and IV estimates for the application effect on vacancy duration, sector matches, starting wages and job duration. Compared to their OLS counterparts, the IV coefficients have for most outcomes the same sign but are larger. Effect sizes are mostly similar across all three IV specifications. For brevity, I will focus on the third specification, which uses layoffs in the last three months as the instrument.

The negative relationship between vacancy filling time and number of referral applications, shown in Figure 3, persists when conditioning on the full set of controls and instrumenting the number of referrals. A one standard deviation increase (about two additional referrals) decreases vacancy duration by six percent. To understand at which stage of the search process vacancy filling rates improve, I also estimate changes in vacancy exit by week after posting date using the same regression specification. Figure 4 plots the corresponding IV estimates, showing that filling rates of vacancies receiving more applications are significantly higher in all weeks up to about three months after vacancy entry, when only a small share of vacancies (< 15%) remains unfilled. Six weeks after posting, when about half of the jobs still need to be filled, effect sizes are largest: vacancies with one additional referral are on average 2.5 percentage points less likely to still be active.

The estimated negative relationship between the number of applications and vacancy

			First stage	
Time 1	ange layoffs:	Prev. 1 mo.	Prev. 2 mo.	Prev. 3 mo.
Asinh laid-off workers		0.059***	$0.057^{***}$	$0.054^{***}$
		(0.001)	(0.001)	(0.001)
F-Stat. excl. IV		2292.284	2675.781	2642.012
Outcome:	OLS		IV	
log(vacancy duration)	-0.027***	-0.036***	-0.017**	-0.028***
	(0.000)	(0.009)	(0.009)	(0.009)
Sector match propensity	0.009***	0.056***	0.045***	0.049***
	(0.000)	(0.005)	(0.005)	(0.005)
Match-weighted experience	6.577***	43.897***	34.520***	32.068***
	(0.243)	(5.358)	(4.937)	(4.964)
log(starting wage)	0.002***	0.011**	0.022***	0.024***
	(0.000)	(0.006)	(0.005)	(0.005)
log(job duration)	-0.006***	0.153***	0.165***	0.142***
/	(0.001)	(0.023)	(0.021)	(0.021)

 Table 2: Main regression estimates

filling time is consistent with a search process where employers delay hiring (to some extent) and wait for better-fitting applicants when few suitable jobseekers have applied. In the extreme case when employers do not want to make any concessions, vacancy duration increases but the profile of hired workers remains unchanged. To study changes in the composition of recruited workers, I next consider how the extent of jobseeker referrals varies with eventual hiring outcomes. Regression estimates for all outcomes are reported in the remaining rows of Table 2.

Note: The regressor is the number of referrals (Mean: 1.135, SD: 1.910). All regressions include the full set of controls as specified in equation (1). The number of referrals is instrumented using the asinh of laid-off workers in the t months prior to job posting in the same region and sector. \* p<0.10, \*\* p<0.05, \*\*\* p<0.01



**Figure 4:** Impact on vacancy exit by week after entry (IV estimates)

Note: The graph plots estimates for equation (1), where the outcome variable is an indicator for still being unfilled in week t after vacancy entry. The number of referrals  $(ref_i)$  is instrumented using the asinh of laid-off workers in the three months prior to job posting in the same region and sector.

Vacancies receiving more referral applications are also able to hire workers who better match the firm's sector. Using the measure of sector match quality  $(M_{kl})$  as outcome, which quantifies how common the hire's previous sector is observed among transitions to the firm's sector, the IV estimate shows that one additional application increases the measure by five percentage points. Since the average match quality in the sample is 31 percent (see Table 1), this is a non-negligible effect. The estimate suggests that a larger supply of fitting job applicants will allow firms to hire workers whose career paths better match the advertised jobs. A comparable impact can be observed for the hires' previous work experience in similar sectors. Per application, firms are able to attract workers with about one month of additional work experience, which compares to an average sector-adjusted work experience of 8 months among all hires.

Better match quality should in turn also lead to higher wages because those workers possess more sector-specific skills and can be more productive. To some extent, this effect also follows mechanically from the wage setting process in Austria. Many collective bargaining agreements specify higher wages for workers with more sector-specific work experience and education. As shown by the IV estimates in Table 2, there exists indeed a positive relation between the number of referrals and starting wages: one additional application leads to hires who have two percent higher earnings in the first year of employment.

To study the longer run implications of better match quality between workers and jobs, I consider changes in job tenure of recruited workers. Mismatched hires will require more training but might also be less likely to stay in the job (even in the absence of better alternatives). While the OLS coefficients on job tenure are negative, estimates of the IV model suggest that more applications allow recruiters to select workers who remain longer with the firm. Figure 5 plots the impact on the probability of still staying in the job by month after job start, showing that this effect is largely driven by separations occurring in the first few months after hiring. The positive impact on the staying probability is the largest in the first four months and shrinks by about 50 percent in the following months to a two percentage point increase per application.

#### 4.3 Worker sorting

When the supply of suitable workers affects hiring outcomes, changes in labor market tightness should also have an impact on the composition of workers across firms. Many workplaces are segregated along worker characteristics such as gender or nationality. This can be driven by both supply and demand factors. Women and men, for instance, choose very different occupations. As a result, firms operating in a stereotypical female or male sector stay gender segregated because mostly workers of one gender apply for these jobs. At the same time, some employers might have reservations about hiring workers of a group that is underrepresented at their workplace, either because of personal biases and preferences or because they find it more difficult to evaluate the applicants' productivity.

**Figure 5:** Impact on job tenure of hires by month after job start (IV estimates)



Note: The graph plots estimates for equation (1), where the outcome variable is an indicator for still being employed in month t after vacancy entry. The number of referrals  $(ref_i)$  is instrumented using the asinh of laid-off workers in the three months prior to job posting in the same region and sector.

These demand-side factors can be more prevalent when labor markets are loose because employers can be much more selective in choosing candidates for a job. Instead, a lower number of suitable applicants might force firms to also consider workers from less preferred groups, which in turn decreases segregation on the firm level. To study the connection between worker shortages and segregation, I relate the number of jobseeker referrals to the recruited workers' gender and nationality, and examine how these relations vary with the worker composition of firms. In a first step, firms are grouped by their share of female and foreign workers prior to each hire. Next, I estimate equation (1) separately for each of these groups using indicators for hiring a female worker and hiring a foreign worker as outcome variables. As instrument for the number of referrals, I use again the sector- and region-specific mass layoffs in the previous three months. The corresponding OLS estimates are shown in Figure A.1 in the appendix.

The two graphs in Figure 6 plot the estimated group-specific coefficients on the number of referrals ( $\gamma$ ). The upper graph shows that firms with low shares of female workers are less likely to recruit women if they receive more referrals for the vacancies. Among firms with more female workers, the estimated coefficients are instead positive. In addition, effect sizes tend to increase with the proportion of females in firms, although the observed pattern is far from monotonic. As shown in the lower graph of Figure 6, a similar but less pronounced relation can be found for foreign hires. More referrals lead to a lower likelihood of hiring non-Austrian workers in firms that have up to 20 percent workers of foreign nationality. In firms with more foreigners, effect sizes turn positive but the estimates are not always statistically different from zero. These results are consistent with the hypothesis that tightening labor markets can alleviate worker segregation. When few workers apply for jobs, employers have to widen their scope of search and also consider atypical workers who are yet underrepresented in their firms.

#### 4.4 Robustness checks

To interpret the estimates as the impact of a changing supply of suitable applicants, I assume that the number of jobseeker referrals can serve as a surrogate measure for a vacancy's overall number of job applications. While other applications are not observed, it is possible to examine how the number of referrals relates to hiring of non-referred jobseekers. If referral applications effectively proxy the overall supply of applicants, differences in the number of referrals should also have an impact on hiring outcomes if vacancies are filled by other jobseekers. To assess this, I divide the estimation sample into vacancies that are filled by referred jobseekers (*Referral hires*) and those that are taken by other applicants (*Outside hires*), and redo the analysis. As shown in Appendix Table A.1, the observed relations also exist for outside hires. In fact, the IV estimates suggest that the impact on vacancy duration is fully driven by vacancies which are filled with non-referred workers, whereas effects on hiring outcomes are comparable across the two groups.



(a) Referral effects on hiring females by firms' female share

(b) Referral effects on hiring foreigners by firms' foreigner share



Due to the lack of direct worker-vacancy links, some of the vacancies might be incorrectly matched to new job spells within firms when using the matching procedure outlined in Section 3.4. If hires on vacancies in the AMS database are representative of all hires (on the firm level), average worker characteristics of matched hires and actual hires should be the same. As a result, incorrect vacancy-worker matches decrease the precision of estimates but do not cause biased results in the analysis of hiring outcomes. As discussed in Section 3.4, direct linkages between workers and vacancies are available for the subset of job postings that are filled through mediation by the public employment service. For these vacancies, hiring outcomes are readily observed, allowing to evaluate if incorrect within-firm matches of workers affect the estimation results in this subsample.

Using outcomes of both matched workers and directly linked workers, I re-estimate the relationship between hiring outcomes and the number of jobseeker referrals in the sample of mediated hires. Table A.2 in the appendix reports the estimation results, showing that *matched* and *exact* outcome measures mostly yield similar results: when employers receive a higher number of referral applications, recruited workers better match the firm's sector, have more sector-weighted work experience, get higher wages and have longer job tenure. For most outcomes, effect sizes are similar. Only for job duration, I find a small and statistically insignificant coefficient when using the exact outcomes. A limitation of this exercise, however, is that mediated hires are not representative of the average hire in the sample. As a result, the firm-level matching procedure should perform better and lead to even more similar results when all hires could be considered.

### 5 Conclusion

Due to a shrinking workforce in many developed economies, firms increasingly struggle to recruit additional workers. Employers can adjust to increasing labor shortages in different ways. Some firms might keep vacancies unfilled and wait until suitable jobseekers apply. This will cause a loss of production but could still be the best solution. Other firms might instead lower their skill requirements and search more broadly for workers. Less restrictive hiring policies can speed up hiring but may involve additional costs for on-the-job training, lower productivity and higher worker turnover. Using a stylized model of the employer's search process, I illustrate how changes in labor market tightness may induce firms to change their hiring policy. When worker shortages become sufficiently severe, employers with limited mismatch costs might start to lower their search expectations to avoid keeping the vacancies unfilled.

To examine these mechanisms empirically, I combine unique firm-vacancy-worker data with a vacancy-level measure of worker supply in Austria, which is derived from job referrals made by the public employment service to unemployed workers. Data on the referred jobseekers' work history allows to gauge how many workers with prior experience in related sectors apply for a job posting. A limitation of this analysis is that the referrals cover only a subset of all applications, and it is unknown how large the total number of applications is for each vacancy. Nevertheless, estimated effects are similar when I focus on vacancies that are not filled by referred jobseekers, which suggests that referral applications serve as an effective proxy for the overall supply of applicants.

Using the inflow of jobseekers from mass layoffs as instrument for the number of referrals, I find that, when job postings receive more applications, vacancy filling takes much less time and hired workers have more sector-related work experience. The increase in match quality between firms and workers is also reflected in positive effects on wages and job duration. Comparing hiring outcomes across firms, I additionally find evidence for a connection between labor market tightness and firm segregation by gender and nationality of workers. In firms that employ many female workers, more women are recruited when vacancies get more referrals but the relation is reversed in firms with few female workers. Similar heterogeneities can be observed for the share of workers with foreign nationality. These findings are consistent with implications from economic theory. When suitable job applicants are scarce, firms delay hiring but also search for workers more broadly. In line with the notion that recruiters discriminate more in slack labor markets, I also find that firm segregation by gender and nationality is enforced when firms receive more applications.

To smooth the transition towards tighter labor markets, additional training and

re-education programs may help jobseekers to prepare early on for jobs that are in highest demand. But more research is warranted on the productivity effects of workerfirm mismatches. Hiring firms might retain mismatched workers due to the absence of alternatives but, if workers lack the necessary skills, productivity might still be lower, curtailing economic output.

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## Appendix





(a) Referral effects on hiring females by firms' female share





	$\ln(\text{vac. dur.})$	Sector match	Wgt. exp.	$\ln(\text{start. wage})$	$\ln(\text{job dur.})$
	Referral hires				
OLS estimates	$-0.028^{***}$ (0.001)	$\begin{array}{c} 0.016^{***} \\ (0.001) \end{array}$	$\begin{array}{c} 10.914^{***} \\ (0.543) \end{array}$	$\begin{array}{c} 0.004^{***} \\ (0.001) \end{array}$	-0.002 (0.002)
IV estimates	$0.012 \\ (0.021)$	$\begin{array}{c} 0.047^{***} \\ (0.011) \end{array}$	$\begin{array}{c} 45.817^{***} \\ (10.959) \end{array}$	$0.018^{*}$ (0.011)	$0.102^{**}$ (0.051)
	Outside hires				
OLS estimates	-0.019*** (0.000)	$0.006^{***}$ (0.000)	4.989*** (0.280)	$0.002^{***}$ (0.000)	$-0.005^{***}$ (0.001)
IV estimates	$-0.022^{**}$ (0.009)	$\begin{array}{c} 0.047^{***} \\ (0.005) \end{array}$	$28.314^{***} \\ (5.495)$	$\begin{array}{c} 0.024^{***} \\ (0.006) \end{array}$	$\begin{array}{c} 0.149^{***} \\ (0.023) \end{array}$

Table A.1: Estimates by type of hire

Note: The regressor is the number of referrals (Referral hires - Observations: 211,170, Mean: 1.463, SD: 2.110 Outside hires - Observations: 970,574, Mean: 1.063, SD: 1.855). All regressions include the full set of controls as specified in equation (1). The number of referrals is instrumented using the asinh of laid-off workers in the three months prior to job posting in the same region and sector. \* p<0.10, \*\* p<0.05, \*\*\* p<0.01

	Sector match	Wgt. exp.	$\ln(\text{start. wage})$	$\ln(\text{job dur.})$	
	Matched outcomes				
OLS estimates	$0.017^{***} \\ (0.001)$	$\frac{11.389^{***}}{(0.581)}$	$0.005^{***}$ (0.001)	-0.002 (0.003)	
IV estimates	$\begin{array}{c} 0.049^{***} \\ (0.012) \end{array}$	$52.772^{***}$ (11.984)	$0.024^{**}$ (0.012)	$0.131^{**}$ (0.056)	
	Exact outcomes				
OLS estimates	$0.031^{***} \\ (0.001)$	$20.954^{***} \\ (0.508)$	$0.005^{***}$ (0.000)	$-0.010^{***}$ (0.003)	
IV estimates	$0.051^{***}$ (0.011)	$\begin{array}{c} 45.323^{***} \\ (10.370) \end{array}$	$\begin{array}{c} 0.034^{***} \\ (0.009) \end{array}$	$0.028 \\ (0.054)$	

Table A.2: Estimates for matched and exact outcomes

Note: N = 192,098. The regressor is the number of referrals. All regressions include the full set of controls as specified in equation (1). The number of referrals is instrumented using the asinh of laid-off workers in the three months prior to job posting in the same region and sector. \* p<0.10, \*\* p<0.05, \*\*\* p<0.01