PRICE DISCOVERY IN LABOR MARKETS:

WHY DO FIRMS SAY THEY CANNOT FIND WORKERS?

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March 15, 2024

Abstract

Managers often report that labor constraints – defined as inability to find workers – are a major obstacle to firms' growth. The phenomenon is puzzling, because economic theory offers a simple remedy: increase wages until the worker is found or hiring is no longer profitable. We explore why firms report labor constraints instead of pre-empting them by increasing wages using administrative data from Germany. We confirm that quasi-exogenous variation in labor constraints slows down firm growth. Wages play a role consistent with basic theory: firms that report constraints initially underpay their workers, increase wages later, and a quasi-exogenous increase in wages alleviates their problems. Why then do firms not increase wages earlier to avoid the problem to begin with? Unlike financial markets, labor markets do not have an easily observable price process. Firms set wages based on their beliefs, and when they underestimate market-clearing wages, labor constraints arise. Consistent with this mechanism, labor constraints increase after quasi-exogenous wage increases in other parts of the economy and are more prevalent in settings where firms are less well-informed.

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Acknowledgment: This study uses the German Job Vacancy Survey of the IAB, Wave(s) 2000-2018 and Linked-Employer-Employee Datasets of the IAB (LIAB) Data access was provided via on-site use at the Research Data Centre (FDZ) of the German Federal Employment Agency (BA) at the Institute for Employment Research (IAB) and subsequently remote data access.

1 Introduction

Capital and labor are the two basic inputs in the production function, and if firms cannot access either of them, they cannot grow. A lot has been said about the inability to access capital, i.e., financial constraints, both in terms of understanding why the constraints arise (Jaffee and Russell, 1976; Stiglitz and Weiss, 1981) as well as measuring them and assessing their empirical importance (Fazzari, Hubbard and Petersen, 1988). However, firms' declarations suggest that labor constraints, i.e., the inability to find suitable workers, may nowadays be a more common barrier to firm's growth.[1]

Labor constraints are puzzling because basic economic theory predicts that they should not occur: if the firm cannot find workers at the wage it is offering, it should offer a higher wage. There should exist a wage high enough so that the firm either finds the workers or no longer seeks them, as employing them does not have positive Net Present Value (NPV) anymore. In either case, the firm should not report that the *inability to find workers* is an obstacle to its growth.[2] Some frictions may prevent firms from increasing wages, and the economic literature has extensively studied why wages are rigid. However, standard explanations proposed in the literature explain why wages do not go down (Stiglitz, 1984). Understanding labor constraints, however, requires an explanation for why wages do not go up – a phenomenon that has not been thoroughly explored.

In this paper, we attempt to understand why firms end up reporting labor constraints, instead of pre-empting this problem with the simple remedy prescribed by economic theory – to increase wages. We conduct an empirical analysis using firm-level administrative data from Germany, which combines vacancy surveys, employment and wage records, and basic financials. The unique advantage of the data is the availability of direct measures of labor constraints. Our analysis confirms a crucial role for wages in mitigating labor constraints, consistent with basic economic theory. Yet, we uncover that information frictions lead to significant delay in firms' responses.

The premise for our analysis is that labor constraints capture real recruiting difficulties and have

[1] In the 2021 Small Business Credit Survey run by US Federal Reserve Banks, 59% of firms declared that it is "very difficult" to fill jobs, with an additional 32% declaring it is somewhat difficult; only 21% of firms declared that credit availability posed a substantial difficulty. Similarly, the IAB Establishment Panel survey run by the German Employment Agency reveals that 9.5% of firms declare labor shortages to be a significant impediment to grow in the nearest future, while 6.4% declare the inability to obtain financing to be such impediment.

[2] The firm may report that high labor costs are an obstacle to firm growth. However, the concern about labor prices is different from labor constraints declarations in which firms complain about not being able to fill vacancy, i.e., not being able to hire the demanded quantity of labor.

consequences for firm outcomes. An alternative is that firms' perceptions about constraints have no informational content. This would be in line with general skepticism about self-reported, subjective measures of economic variables because of response biases (see Hyman (1954); Furnham (1986); Podsakoff et al. (2003)). We proceed to test this premise in two steps and, consistent with the broader benefits of self-reported measures discussed by D'Acunto and Weber (2024), we find that labor constraints declarations do have real consequences.

First, we document that labor constraints map into real recruiting difficulties, as evidenced by longer job searches and higher chances of failure to fill a vacancy. Second, we find that labor constraints reduce firm growth. To uncover this relationship, we need to address reverse causality of faster growing firms being more likely to report labor constraints due to their high labor demand. We do this using a shift-share strategy based on firms' occupational structures and nationwide occupation-level labor shortages. Quasi-exogenous increases in labor constraints identified in this way lead to reduced growth in firms' employment, sales, and profitability.

We then turn to the core part of our analysis: If labor constraints are a real obstacle to firm growth, why do firms not resolve it by increasing wages? It is possible that other frictions are the first-order determinant of labor constraints, and hence a reasonable variation in the wage level neither causes nor can resolve the problem.[3] However, our analysis of labor-constraint declarations and wage patterns lends support to basic economics and indicates that wages do play a crucial role in determining labor constraints. We show that firms that initially underpay their workers are more likely to be labor-constrained. Furthermore, we demonstrate that, following labor constraints declarations, firms start paying their workers more.

But does increasing wages help solve the labor constraints problem? Firms reporting labor constraints tend to grow faster, which may affect both hiring and wages, and hence analyzing the causal effect of their own wage increases is subject to endogeneity concerns. To address them, we isolate quasi-exogenous variation in wages from central wage bargaining. Over half of the German economy is covered by collective bargaining agreements, and outcomes of the bargaining process effectively provide variation in wages that firms take as given. Using industry-year and occupation-year measures of the wage evolution induced by collective bargaining as quasi-exogenous sources of wage variation in all firms, we find that higher wages significantly reduce labor constraints.

[3]This could be the case if non-monetary reasons, e.g., attractiveness of employer location, are first order determinants of labor constraints. In such case, paying exorbitant wages may reduce constraints, but moderate variation may have no effect. Such possibility would be consistent with the results of Mueller et al (2022), who find that offering to pay a higher wage has small impact on the pace of filling the vacancy.

Our results paint a picture that is consistent with basic economic theory: firms that initially underpay their workers suffer from labor constraints, which has real adverse impact on firm growth. These firms later increase wages, which alleviates the constraints. Why then do labor constraints arise to begin with and why do firms not increase wages earlier to avoid the problem?

We propose an explanation based on firms being imperfectly informed about the changing equilibrium level of wages. Unlike markets for financial assets or commodities, labor markets do not have a publicly observable and universally applicable price process that aggregates the relevant information and equates supply and demand. While many aggregate wage statistics exist, both firms and workers may have difficulties in determining the equilibrium wage level in a particular area, occupation, and experience level, especially in periods in which the economy undergoes large changes. Each labor market participant forms individual beliefs about the price of a relevant unit of labor but, we argue, the accuracy of these beliefs may be limited. As a result, buyers of labor (firms) may often offer a price that is too low to be accepted by sellers (workers), which gives rise to "labor constraints". We present three pieces of evidence that support this mechanism and demonstrate that labor constraints tend to arise in settings in which the information is most likely to be imperfect.

First, we show that labor constraints arise when fundamental economic shocks drive up wages in other parts of the economy, which makes it difficult for firms to quickly understand the new equilibrium and adjust their wages. We provide evidence consistent with this phenomenon using quasi-exogenous variation from central wage bargaining to show that firms suffer labor constraints when wages in *other parts of the economy* increase one year earlier. Specifically, we measure the bargaining-induced wage evolution by industry and compute a leave-one-out average level of local wages in other industries. We find that wage increases in other industries lead to a delayed and significant increase in declarations of labor constraints, as well as a subsequent increase in wages, at firms in the focal industry. Once wages are adjusted, labor constraints are alleviated. This adjustment process evolves over a period of two years, emphasizing the substantial delay in adjustments to shocks in other parts of the economy.

For the second and third pieces of evidence, we are inspired by the market microstructure literature on price discovery and identify settings in which firms face varying degrees of uncertainty about wages. Specifically, in an analogy to measures of stock price non-synchronicity (Roll, 1988; Durnev et al., 2003), we hypothesize that firms face higher uncertainty about wages if the local labor market is less synchronized with the overall economy. Since national wages are more com-

monly measured and reported by statistical agencies, they are easier to observe. Thus, firms in counties where local labor market wages are more strongly correlated with national wage trends can form more accurate beliefs about the local equilibrium level of wages. Consistent with our predictions, labor constraints declarations are less common in these counties.

Finally, inspired by a distinction between informed- and noise-traders commonly made in models of trading in financial markets (Kyle, 1985; Glosten and Milgrom, 1985), we compare settings in which the firm is likely to be more or less informed about prevailing market wages. A firm may be an informed trader or a noise trader depending on whom they hire and how common a given occupation is in its workforce. Intuitively, this analysis compares recruitment in core occupations (e.g., production workers in a manufacturing firm) to peripheral occupations (e.g., an accountant in a manufacturing firm). The importance of information predicts that firms are more likely to know the prevailing wage level in their core occupations and thus are less likely to face labor constraints. This prediction is confirmed in the data: firms face fewer recruiting difficulties, in particular those related to wage demands, for core occupations, as evidenced by a lower frequency of both initial wage offers being declined and higher pay for a new hire than initially planned.

The role of imperfect or slow price discovery in labor markets has important implications for firms and policymakers. For firms, it shows that additional investments in information gathering and making wage determination more flexible is likely to be a successful strategy in addressing labor constraints, which have recently intensified. Consistent with that, in recent years firms are increasingly using tools for salary benchmarking (Cullen, Li and Perez-Truglia, 2022) as well as integrated labor market insights from providers such as Lightcast (formerly Burning Glass) to keep track of labor market dynamics. For policymakers, it suggests that additional initiatives related to fast and accurate wage reporting by public statistical agencies, as well as to pay transparency, may meaningfully alleviate labor constraint problems.

Our findings explain why firms sometimes fail to fill a vacancy, even though doing so would be profitable and would be possible by offering the market wage. CFOs surveyed by Jagannathan et al. (2016) often report that limited availability of qualified managers and manpower is the reason why they use discount rates higher than their cost of capital in their NPV calculations and hence forgo apparently profitable projects. The adverse impact of labor constraints can also be observed when directly analyzing firm outcomes, as shown by D'Acunto, Weber and Yang (2020) and Le Barbanchon, Ronchi and Sauvagnat (2023). Interestingly, while these two studies both show adverse impact on firm growth, they report mixed findings on the impact of investment, which highlights

the complexities of potential substitution and complementarity effects between capital and labor (Bena, Ortiz-Molina and Simintzi, 2022; Gechert et al., 2022; Babina et al., 2024; Gardberg, Heyman and Tåg, 2023). While we also document the adverse impact of labor constraints on firm growth as a premise for our analysis, our focus is on understanding why firms let labor constraints arise in the first place.

Our question of why price adjustments do not always successfully facilitate transactions in the labor market shares some similarities with the question about why interest rates do not always clear credit markets and why credit rationing may exist (Stiglitz and Weiss, 1981). Our answer, however, differs, as instead of pointing to the role of adverse selection, we highlight the importance of delayed and imperfect adjustments of firms' beliefs about wages. Doing so reveals that concepts such as price discovery or price informativeness, extensively studied in the context of financial markets, are also helpful for understanding firms' actions in the labor market.

While an established literature in labor economics has studied why wages do not go down (Stiglitz, 1984; Blinder and Choi, 1990; Kahn, 1997; Bewley, 1999; Altonji and Devereux, 1999), our contribution is to explain why wages do not go up and instead labor constraints arise. Several papers have analyzed the reasons behind skill shortages, such as technical change (Haskel and Martin, 2001), educational regulation (Cappelli, 2015), occupational licensing (Friedrich and Hackmann, 2021), and migration policy (Kerr et al., 2016), but unlike us, they do not focus on the question why prices do not adjust to clear the market.

Related research on hiring (Oyer and Schaefer, 2011) highlights the importance of informational frictions, in particular firms' uncertainty about the quality of candidates (Pallais, 2014; Burks et al., 2015; Pallais and Sands, 2016; Bassi and Nansamba, 2021; Stanton and Thomas, 2021; Friedrich, 2023) or potential applicants' uncertainty about firm fundamentals (Hacamo and Kleiner, 2022). Our findings demonstrate the importance of uncertainty in firms' beliefs about wages, complementing recent work on the role of workers' beliefs about outside options (Jäger et al., 2024).

2 Data

2.1 Data Sources

Our data source is the Institute for Employment Research (IAB) of the German Federal Employment Agency. In our regressions, we use two main datasets: the Job Vacancy Survey and the Establishment Panel. In addition, we create supplementary variables based on worker-level employment records data (LIAB) and other auxiliary datasets.

The IAB Job Vacancy Survey (SE) is a repeated cross section with over 230 thousand observations at the establishment-year level, covering years between 2000 and 2018 and between 7,500 and 15,000 unique establishments every year, with the average being close to 12,000. Each year, the firms[4] are filling out either written or online questionnaires that ask about vacancies, recruiting activities and challenges, as well as a specific set of questions about the last instance of successful and unsuccessful hiring. The main variables collected include the number and structure of vacancies, future personnel requirements, and current and future expected economic situation, as well as information about the characteristics of the last hire, search duration, as well as difficulties and decisions associated with the recruiting process. The main measures remain the same or similar in all waves of the survey, but occupational and industry classifications change over time, limiting the ability to use all waves of the survey in some analyses.

The population from which firms are sampled are all establishments in Germany with at least one employee subject to social security contributions. Selected firms are contacted by mail in October, receive the questionnaire, and are asked to participate in the survey. A few weeks later, a second mailing with a reminder is sent out. Most firms send responses back between end of October and beginning of December, but the responses are usually collected until beginning of January. The average response rate is 18.5% and the sampling is stratified to ensure that the survey is representative along East and West Germany, 7 bins of firm size, and ~20 industries. The Vacancy Survey is merged with firm-year-level administrative records (BHP dataset), which contain information about annual employment levels and wages for the establishment as a whole, as well as for pre-specified groups of workers of different age, sex, education, or occupational group (Gurtzgen et al., 2023).

[4]We use firm and establishment interchangeably throughout the paper. All surveys are conducted at the establishment level, i.e., answers describe the characteristics of a particular location of operations and not a set of locations owned by the same firm.

The IAB Establishment Panel (EP) covers years 1993-2019 and follows establishments over time. Between 1993 and 1995, the panel included ~4,000 establishments, between 1996 and 1999 ~10,000, and in 2000 and beyond over 15,000 establishments. The data is collected via interviews with a target person that is knowledgeable about the firm's operations. The interviews are usually conducted face-to-face and an average interview lasts 36 minutes. The typical average response rate is close to 60%, but it varies by the type of establishment: among establishments that were surveyed in the past, the response rate is usually higher than 80%, while the new establishments that are added to the sample over time have usually ~25% response rate. The interviews are checked for quality and consistency, and a large fraction of establishments is contacted by phone with a follow-up request to clarify/correct some information.

Every year, the survey contains a basic module with information about the firm's employment and key characteristics. In addition, the survey contains a set of rotating additional modules about various areas of firm operations, e.g., recruiting and staffing challenges, innovation, cooperation with public authorities, etc. Given the focus of our study, many of our analyses will focus on years in which the "Staffing Challenges" module was included, which was the case approximately every two years. We also focus on firms with at least 10 employees, for whom recruiting and employment measures exhibit more meaningful variation. Overall, our main sample includes 77,330 establishment-year observations and 25,190 unique establishments. Using unique identifiers, the survey is linked with firm-year and worker-level administrative employment and wage records.

Employer-Employee Linked Data (LIAB) is a dataset of worker-level employment records whose two versions offer cross-sectional and longitudinal information about workers. The cross-sectional variant of the data, LIAB-QM (Graf et al., 2023), allows us to observe all workers employed in the establishments surveyed in the EP data. While we do not perform worker-level analyses, we use worker records to measure the occupational structure of establishments and occupation-level wages, which play an important role in some of our analyses. LIAB data is constructed by identifying all workers employed in a given establishment on June 30th of a given year and reporting characteristics of an employment spell, such as the daily wage, valid as of June 30th. We observe the classification of occupations according to German standard KldB 2010, which is similar to International Standard Classification of Occupations (ISCO) codes, and calculate occupational aggregates based on two-digits codes.

The longitudinal variant of the LIAB data, LIAB-LM (Ruf et al., 2021), provides full employment histories of workers employed at a subsample of firms surveyed in the IAB Establishment

Panel. For our analysis of wage shocks, we use observed employment transitions in the panel data to construct a matrix of worker flows between occupations. We calculate the likelihood of workers moving from one occupation to another, which then allows us to construct a synthetic *similar occupation* and calculate its wage level.

2.2 Key Variables

The key dependent and independent variables used in our analysis are measures of labor constraints and wages. We describe them in detail here, while also briefly discussing a larger set of variables that serve as controls or dimensions of heterogeneity in our tests.

Labor Constraints Measures Both of our main datasets, SE and EP, contain measures of labor constraints. In the SE data, the labor constraints measure is a binary variable that takes value of one if the firm declares that "not having enough suitable workers" was preventing it from "making full use of its economic opportunities in the past 12 months". 9.5% of firms in the sample report that they are labor constrained, which is more than the 6.4% of firms that report financial constraints as an obstacle in an analogously-defined question.

In EP, the labor constraints measure is a binary indicator of whether the firm considers "Staff shortage" to be among problems affecting the establishment over the next two years. This question is asked when additional module about staffing problems is included in the survey, which happens roughly every two years. Despite the exact formulation and the time horizon of the question being different than for the SE measure, the magnitudes of the two variables are similar, with 12.2% of firms reporting labor constraints in the EP data on average.

In addition to the main measure of overall labor constrains, SE data also contains other related variables. Part of the questionnaire related to the last recruitment process contains a measure of "experiencing difficulties in filling this vacancy", which we denote as *search difficulties*. The difficulties are reported by 24.8% of firms, which is greater than the average likelihood of reporting labor constraints partially because it conditions on hiring over the last 12 months. Firms reporting difficulties are then asked what kind of difficulties they experienced, such as qualifications of applicants being too low or wage expectations being too high. The data also contains search duration in days, which, while affected by many factors, may also reflect difficulties in filling the vacancy. Finally, firms also report whether they had to pay a higher wage than they initially expected.

In both the SE and EP datasets we can also compute the vacancy ratio , defined as the number of open vacancies to the number of current employees. In the SE data, the ratio includes vacancies to be filled immediately and vacancies to be filled over the next 12 months. In the EP data, only the vacancies to be filled immediately are included. As a result, the average constructed vacancy rate in the EP data equals 1.5%, while in the SE data it equals 2.9%.

Wages and Collective Bargaining Our main analyses involving wages are performed in the EP data. We calculate them as the average daily wage of all workers, or – in selected tests – of all new workers (defined as those who joined the firm over the last 12 months) and all incumbent workers (who joined the firm earlier than in the last 12 months). The daily wages come from administrative employment records and represent contractual wages valid as of June 30th of a given year.

In the SE data, we measure overall firm level of wages based on the average daily wage of all workers coming from administrative employment records. In regressions that analyze the wage paid to the last hire, we use firms' reports of that monthly wage from the survey.

To isolate quasi-exogenous variation in wages, we rely on central-bargaining-induced wage levels. In the EP data, the firm reports whether it is bound by a centralized collective agreement. If so, the firm is asked whether it pays wages "above the collectively agreed scales" to workers subject to the agreement. We identify a subset of firms that are subject to a centralized collective agreement and declare that they do not pay wages above the agreed scale, and use the average level of wages in that subset to proxy for the wage levels negotiated in the centralized collective agreement. We provide more details about the process of central bargaining in Section 6.

Other Variables Other variables used in our analysis are more standard. We measure employment with the total number of workers employed as of June 30th according to administrative records. Sales are based on total volume of sales in EUR in the previous fiscal year, as reported by the firm in the EP survey. Capital expenditures in EUR also come from EP reports and reflect the total amount spent on investment in the previous year. Unfortunately, to ensure a greater response rate, the EP data does not contain quantitative measures of profitability. Instead, only a qualitative measure of the profit situation is collected. Based on that measure, we define a binary indicator for "sufficient" or higher profit situation as reported by the firm.

2.3 Sample Descriptives

Summary statistics for key variables from both datasets are presented in Table 1. The average establishment in our EP sample has 261 employees and sales of EUR $164M per year, which grow at 4.5% annual rate. The average daily wage for incumbent workers is EUR 76.4, which corresponds to a monthly wage of EUR 2,324.

The focus of our analysis and a unique feature of our data are measures of labor constraints, which are not present in standard firm-level datasets. Figures 1 and 2 describe the variation of these measures across time and a set of firm characteristics.

Labor constraints have always been present but have become much more pronounced in recent years (Figure 1, Panel A). While in 1990s and 2000s the average share of labor constrained firms was often below 10%, after 2010 it always exceeded 10% and reached as much as 30% in the most recent survey in 2018. The vacancy rate, which is measured more regularly, tracks labor constraints declarations closely, indicating the connection between firms' declarations and their recruiting practices.

Labor constraints vary considerably by industry (Panel B). While all industries display a sizable share of labor-constrained firms, the hospitality sector and professional services, including education and health, are particularly affected. This finding illustrates an interesting subtlety of labor constraints: they may be severe both in industries employing mostly low-wage workers, following observations made already by Habakkuk (1962) that workers move away from least desirable jobs, and in those employing highly-paid specialists, that often require specific and difficult to acquire skills.

The size gradient in labor constraints declarations is hump-shaped (Panel C) but the variation is relatively small. The smallest firms are less labor-constrained than medium-sized ones, but a further increase in firm size reduces the prevalence of labor constraints declarations. The relationship with firm age is U-shaped but the differences between quintiles are also limited. Overall, the variation by firm size and age is smaller than variation by industry or over time.

3 Labor Constraints: Conceptual Primer

As shown in Table 1 and Figure 1, around 10% of firms at any given point in time, and 30% of firms more recently, declare being labor constrained. This is a puzzling phenomenon in light of

standard economic theory. To set up the problem more concretely, we introduce a simple model of firm operations and hiring, and discuss the potential meaning and origins of labor constraints in that context.

Suppose that a firm considers a new project, which would bring revenue of R but would require hiring a worker who receives wage w. In addition, the firm expects profits from other projects today ($t = 0, ROF$) as well as in the future ($t > 0$). The value of such a firm can be written as:

$$V_0 = (R - w) + V_{0,ROF} + \beta V_1,$$

where $V_{0,ROF}$ represents profits from the *rest of the firm*, i.e., all other projects today, and V_1 represents firm value next period, which comes from future projects and is discounted at rate β. In the simplest case, when the value of the rest of the firm today ($V_{0,ROF}$) and the future value of the firm (βV_1) does not depend on what happens with the new project, the new project has positive Net Present Value (NPV) if the firm can hire a worker at a wage that is smaller than the project's revenue ($w < R$). Suppose that there is a competitive labor market with a prevailing market wage $\bar{w}$. In such a setting, the firm can hire a worker if and only if they offer a wage equal to or higher than the market wage ($w \geq \bar{w}$).

How should we think about a firm reporting labor constraints, i.e., declaring that they cannot find the worker that they need? In the context of the simple model, if the firm cannot hire a worker it is because the wage that they are offering is below the prevailing market wage ($w < \bar{w}$). If the firm knows the prevailing wage, and if there is any cost to unsuccessful recruiting, e.g., because of time during which the position remains unfilled or because of resources devoted to the recruiting process, labor constraints should never arise. The firm should either offer the market wage, if the project is positive NPV at that wage level (which is the case if $R \geq \bar{w}$), or abandon the project and not look for a worker (if $R < \bar{w}$). In both cases, they would not declare that they cannot find workers.

Yet, the prediction of this simple model is not borne out in the real world: many firms do complain about not being able to find workers. What could be missing from the model?

Labor Constraints as Noise One possibility is that the complaints do not really represent systematic labor constraints. Firms reporting labor constraints are hiring at a usual rate and do not systematically differ from other firms in terms of hiring and staffing, and the declarations are just noise, or cheap talk, in the sense that they do not have impact on any actions or outcomes of the firm. In such a case, the prediction of the model would be correct: true labor constraints with

systematic consequences never arise. Section 4 explores this possibility in the data by analyzing if measures of hiring process success are systematically different for firms reporting labor constraints. We find significant differences, suggesting that the recruiting process at firms reporting labor constraints is indeed less successful and reports of labor constraints are meaningful.

Labor Constraints without Consequences for Firm Performance A second possibility is that labor constraints are real yet harmless. Firms reporting labor constraints do have a hard time finding workers, but they are somehow able to offset that with other actions, such as improved retention of existing workers, reorganization, or technological change. In the context of our model, the firm does not hire a worker but is able to generate profits $R - \bar{w}$ either by increasing the efficiency of their existing workforce or completing the new project with automation. Thus, there is nothing suboptimal in offering a below-market wage and suffering from labor constraints, because the firm's growth and performance are not affected.

If that were the case, labor constraints would not be correlated with any systematic differences in measures of firm growth or profitability, while they would be correlated with higher capital expenditures that capture substitution from labor to capital. We investigate this possibility in Section 5 and find that firms reporting labor constraints experience lower growth of employment and sales as well as lower profitability, but no significant changes in capital expenditures.

Labor Constraints due Mainly to Non-Wage Reasons A third possibility is that labor constraints are real and harmful, but are not optimally addressed by paying higher wages, as they primarily arise from non-pecuniary considerations that our model does not feature. It could be the case that the firm is offering a wage that is comparable to other similar firms, but for other reasons is not able to find workers. For example, the firm may be located in a remote region, which may lack some amenities that are essential to most workers, such as schools, housing, or healthcare. Such a firm could, in theory, pay exorbitant wages to convince workers from other regions to move, but a cheaper way of adjustment might be providing the amenities that are missing, e.g., building a school for employees' children.

The representation of that in our model would be a case in which the firm offers wage $\bar{w}$ but doing so still does not guarantee hiring a worker for reasons that are not modeled. If that were the case, we would not observe that wages in firms reporting labor constraints are initially lower. We also would not observe that a reasonable wage increase helps to resolve labor constraints, because only a non-wage adjustment (e.g., providing schooling to employees' children) could alleviate scarcity absent unrealistically high wage increases. Yet, as we demonstrate in Section 6, firms re-

porting labor constraints do initially underpay their workers, and quasi-exogenous wage increases with magnitudes that are in line with wage changes in the overall economy help to alleviate labor constraints.

Imperfect Information on Prevailing Wages A fourth possible explanation does receive support in the data: firms are imperfectly informed about the prevailing market wage. In the context of our model, the firm does not observe the true $\bar{w}$ but rather has a belief about the market wage $\tilde{w} = \bar{w} + \varepsilon$, where ε has zero mean and non-zero variance. Labor constraints arise when a firm's belief is below the market wage:

$$LaborConstraints = \begin{cases} 1 & if\ \varepsilon < 0 \\ 0 & if\ \varepsilon \geq 0 \end{cases}$$

When a firm offers a wage lower than $\bar{w}$, the recruitment fails and the firm reports labor constraints. The firm may then gradually learn about the prevailing market wage, adjust its compensation policy, and solve the labor constraints problem, but such a process can take many months. It is worth noting that labor constraints are an asymmetric phenomenon, i.e., even though ε is zero-mean, positive and negative epsilons do not cancel on average. If a firm offers an above-market wage, they do not differ from another firm offering the market wage as far as labor constraints are concerned, as both firms would report no constraints. It is only the underestimation of market wages that generates the phenomenon we are interested in. That said, with higher dispersion of beliefs about the market price, some firms will have excess costs of labor conditional on hiring, which may affect firms' profitability.

Section 7 demonstrates that labor constraints are more likely to arise when shocks to the prevailing market wage occur in other sectors of the economy, because firms adjust wages in response to these shocks with a delay. In addition, labor constraints are most prevalent in markets with less information about the prevailing market wage, and for recruiting processes in occupations in which the firm rarely recruits. All these pieces of evidence are consistent with imperfect information about market wages being a driving factor behind labor constraints.

Other Explanations Imperfect information is not the only remaining possible explanation of labor constraints. Other possibilities include spillovers between the wage offered in the current project, w, and either the value of the rest of the firm today or value of the firm in the future. It is possible that offering a high wage to a new worker creates demands for wage increases among existing workers, which otherwise would not arise ($\frac{dV_{0,ROF}}{dw} < 0$). It is also possible that today's

prevailing market wage is abnormally high and paying it today, due to downward wage rigidity, increases wages that the firm has to pay in the future compared to a scenario in which no worker is hired today ($\frac{dV_1}{dw} < 0$). It is also possible that firms would find it optimal to pay a higher wage, but they are unable to do so due to financial constraints. Our cursory exploration suggests limited evidence of these channels in our setting, but we leave these mechanisms for future research.

Existing Theories of Financial Constraints and Wage Rigidities The question of why labor constraints arise shares many similarities with a long-standing question in the finance literature: why do financial constraints and credit rationing arise? In both cases the fundamental question is why prices – wages or interest rates – do not adjust to facilitate the transaction. The traditional explanations of financial constraints, however, cannot explain the existence of labor constraints. Seminal works by Jaffee and Russell (1976) and Stiglitz and Weiss (1981) show that lenders may find it optimal to ration credit because charging higher interest rates leads to a negative selection of borrowers and a market-clearing level of interest rates may not exist. This mechanism does not apply to labor constraints. Offering a higher wage does not lead to a negative selection of workers; if anything, there may be positive selection because some high-quality workers have better outside opportunities and are only interested in work for relatively high wages (Weiss, 1980).

The question why firms do not adjust wages is also analogous to a long-standing question in labor and macroeconomics on why wages are rigid (Stiglitz, 1984; Blinder and Choi, 1990; Campbell III and Kamlani, 1997). However, this literature is concerned with wages not going down and often explicitly defines wage rigidity as "the observation that wages cannot be adjusted downwards" (Goette, Sunde and Bauer, 2007). Several theories of downward wage rigidity exist, and the explanations they propose include minimum wage legislation or the efficiency wage hypothesis. These explanations, however, do not explain why firms would not increase wages. In fact, they often point to the benefits of paying higher-than-market wages.

Overall, while conceptually closely related, the existing literature on credit rationing and downward wage rigidity does not offer an explanation for the phenomenon of labor constraints. This is the motivation for our study.

4 Are Labor Constraints Real?

The first explanation of the labor constraints puzzle that we tackle is that there is no puzzle: declarations of labor constraints may not capture any relevant economic phenomena, but rather man-

agers' tendency to complain. Perhaps a given share of business owners always complains that the business is slow, and because hiring is an important part of business, they may occasionally concentrate on difficulties with finding workers. Alternatively, firms may truly experience some salient idiosyncratic hiring difficulties, which shape managers' perceptions but have no systematic impact on firm hiring and staffing. In these cases, declarations of labor constraints only constitute noise without real implications.

Table 2 correlates labor constraints measures with other variables that capture the average efficiency of the hiring process in a more tangible and more easily interpretable way: search duration that the firm reports for their last hired worker (from the vacancy survey, SE), an indicator whether the firm failed a worker search over the last 12 months (SE), and the vacancy rate (both SE and EP), defined as the ratio between the number of open vacancies and the total number of workers. Labor constrained firms search almost 30% longer, and are 50 percentage points more likely to report a failed search over the last year. In addition, their vacancy rates are substantially higher: while the measurements of labor constraints and vacancy rates differ across the two data sources, as discussed in section 2.2, we find robust differences between constrained and unconstrained firms, with constrained firms reporting 35–40% of a standard deviation higher vacancy rates than unconstrained firms. While estimates from the SE sample rely on cross-sectional variation across firms, we can leverage the panel dimension for the EP sample to analyze whether declarations of labor constraints temporarily coincide with higher vacancy rates once establishment fixed effects are included. Column 5 of Table 2 demonstrates that vacancy rates are substantially higher in years in which firms declare being affected by labor constraints.

Finally, columns 6 and 7 of Table 2 analyze whether individual firms' labor constraint declarations are correlated with common recruiting difficulties and broader skill shortages. To capture these broader market conditions, we construct a firm-specific shift-share measure of labor constraints based on market-level recruiting difficulties. Specifically, we measure average recruiting difficulties nationally by 2-digit occupation and year (as reported by employers),[5] and then compute a firm-specific measure of labor market constraints using the establishment's own occupational employment shares as weights for each occupation-based measure of market-level constraints. The results show that firms are more likely to be labor constrained if they employ more

[5]Using merged employer-employee data we assign the labor constraints declarations of firms to all their workers. We then calculate average measures of hiring difficulties by collapsing worker-level data to the level of 2-digit occupation-by-year.

workers in occupations that generally involve recruiting difficulties. This relationship holds after controlling for firm fixed effects, supporting how contemporaneous constraints at the market level are felt by individual firms.

Overall, labor constraints measures are coherent measures of firms' difficulties with finding workers that correlate with vacancy rates as well as with search duration and outcomes. Firms with managers complaining about labor constraints do take different actions and face different outcomes in the recruiting sphere. Contrary to idiosyncratic complaints, reported labor constraints are related to average recruiting difficulties at the market level consistent with broader skill shortages.

5 Labor Constraints and Firm Growth

Perhaps labor constraints are indeed real (Section 4) but are they in fact harmless? That is, when firms face labor constraints, they have to recruit longer and fail to fill the position more often, but perhaps they are able to adjust so that their business operations are not really affected. Perhaps the unmet labor demand is substituted with technology, outsourcing, or reorganization, which rationalizes work of existing employees or improves their retention? If that were the case, we would find that reporting labor constraints has no effect on any real outcomes.

Yet, when examining the relationship between labor constraint declarations and firm growth outcomes, endogeneity concerns complicate the analysis. The direction of potential bias is ex-ante unclear: labor constrained firms could be poorly managed and underperforming, which would discourage potential hires; but the firm could also be successful and growing rapidly, thus having an extraordinary labor demand. In either case, labor constraint declarations would then proxy for firm quality, and one may be concerned that using it as an independent variable does not inform us about the true effect of labor constraints due to omitted variables.

To tackle this concern, we conduct the analysis with firm-fixed effects to account for time-invariant firm characteristics, and we again utilize the firm-specific shift-share measure of labor constraints discussed in the previous section, which provides quasi-exogenous variation in labor constraints stemming from broader labor market conditions.

Table 3 reports results for the relationship between labor constraints and firm growth outcomes of employment, capital expenditures, sales growth, and firms' profit situation. Odd columns regress these outcomes on firms' own declarations of labor constraints. Firms that report labor constraints have faster growth of employment and higher capital expenditures today, which also translates into

higher sales growth and higher likelihood of profitability next year. These result suggest that the reverse causality concern is first order in this context, as successful firms are likely growing faster and trying to hire large number of workers, which generates labor constraints.

Interestingly, the results in even columns of Table 3, which rely on the quasi-exogenous measure of labor constrains, paint a very different picture. Firms exposed to higher labor constraints because of their occupational mix and outside labor market conditions have significantly lower employment growth today. Firms facing a one standard deviation higher extent of labor constraints experience around a 1.3 percentage points lower employment growth rate. Those firms do not have significantly higher capital expenditures: while the coefficient is positive, consistent with raising capital expenditures to substitute scarce labor with technology, the estimate is very noisy. Overall, lower inputs today translate into slower sales growth next year, with one standard deviation higher constraints leading to 1.2 percentage points lower sales growth, which is close to 25% of the average sales growth in our sample. This in turn leads to a negative effect on profitability. The precision of these two estimates is somewhat limited but they are statistically significant at the 10% level

The results presented in this section demonstrate that labor constraints do have real economic consequences. Firms' own declarations are correlated with firm growth, and thus their regression coefficients do not capture the causal effect of interest. Yet, quasi-exogenous variation in labor constraints affects firms in a significant and intuitive way: labor constrained firms grow their employment more slowly and do not substantially increase their reliance on capital. As a result, their future sales growth and qualitative measure of profitability decline. While we cannot unambiguously assert that increasing wages to eliminate labor constraints would be optimal for firm value in all cases, our results suggest that firms suffering labor constraints are likely to grow less.

6 Labor Constraints and Firms' Wages

So far we have documented that labor constraints are a real phenomenon and slow down firm growth. This raises the question why firms do not prevent these situations by setting wages appropriately. One rare scenario is that individual firms cannot raise workers' wages in a highly regulated environment with collective bargaining, and thus a labor shortage can arise and persist. This regulatory restriction helps explain for example the nurse shortage at public health-care providers in Denmark (Friedrich and Hackmann, 2021) but is not a factor for collective bargaining in the private

sector in Germany, which essentially negotiates wage floors, because it allows firms to pay wages above the negotiated levels.

Another hypothesis for less regulated markets is that wage increases would not be optimal to solve labor constraints because they mainly arise due to non-wage reasons, especially from a lack of amenities that workers value highly. Rather than offering a massive pay increase to compensate workers for lack of high-quality education services in a remote location, a firm may choose to offer a private school for employees' children. Yet, if that were the case, we would not expect labor constraints declarations to be associated with wages in any way, which is the question that we turn to in this section.

6.1 Firm's Own Wages

Table 4 shows that a higher average level of wages last year is associated with lower labor constraints today. This result is obtained in the panel of firms without including firms' fixed effects, and hence should be interpreted as a between-firm comparison. Consistent with basic economic intuition, firms that underpay their workers are more likely to report labor constraints. The relationship is present in both SE and EP datasets, and is also visible when the vacancy rate is used as a proxy for difficulties with finding workers.

How do firms respond to labor constraints in terms of their wage policies? Figure 3 demonstrates the evolution of the average wage of new hires around labor constraints declarations. We present coefficients from a regression of the logarithm of the average daily wage of workers hired over the last 12 months on lags and leads of labor constraints declaration and a set of controls, including firm fixed effects. Observations outside the event window from year -4 to 4 are included in the regression and coefficients normalized to zero. Hence, the coefficients inform us how wages change around the labor constraints declaration relative to the average wage for new hires in a given firm. Between 4 and 2 years before the labor constraints declaration the coefficients are close to zero, indicating that the firm pays their usual wage. However, beginning in the year before the actual declaration, the firm starts increasing the average wage to new hires, which reaches the highest level one year after the constraints declaration. Relative to its usual wage level, firms pay 4% higher wages one year after declaring that they are labor constrained.

Naturally, the wage response analyzed in Figure 3 is endogenous: firms adjust their wages given their business conditions and find it optimal to increase them in periods during which they

also report being labor constrained. Yet, the fact that firms reporting labor constraints initially underpay their workers, and that labor constraints declarations then coincide with future wage increases suggests that labor constraints are a wage-related phenomenon.

The evidence presented so far, however, fails to address three issues. First, we observe that firms increase wages but do not know if it helps to alleviate labor constraints. Second, labor constraints and wage policies are co-determined and endogenous, and hence we do not know if the wage level has causal impact on labor constraints. Third, we observe that firms increase wages after labor constraints declarations, but still do not know why firms allowed themselves to reach a point when labor constraints became an issue, as opposed to increasing the wages earlier. We address the first two issues in Table 5 and move to the third issue in the next section.

6.2 Central Bargaining-Induced Variation in Wages

To investigate if higher wages reduce labor constraints, we isolate quasi-exogenous variation in wages coming from central wage bargaining. More than 50 percent of workers in Germany are covered by a collective bargaining agreement. These agreements often set baseline wage levels through negotiations between labor unions and employer associations. The negotiations typically happen every two years and result in a negotiated baseline wage and other provisions, such as special bonuses. The baseline wage is then used to calculate wages for individual workers taking into account their position and seniority. Negotiated wages are floors and firms are free to pay higher wages.

The bargaining coverage is rather complex. The most common form of bargaining happens at the industry level, e.g., construction or metal manufacturing. The bargaining often takes place by state, but the process in different states is highly correlated. Industry-level agreement sets wages for different salary groups, and assignment to a particular group may vary by occupation, seniority, leadership position, and firm characteristics (Jäger, Noy and Schoefer, 2022). Worker-level assignment to specific collective bargaining agreements is not available in our data and deriving ex ante measures of applicable bargaining wages has traditionally been challenging.

To tackle this problem, we propose an ex-post measure of bargaining-induced wages. In the EP data we observe which firms are members of an employer association and subject to collective bargaining. Specifically, we can isolate firms declaring that 1) they are bound by an industry-wide wage agreement; 2) do not pay wages exceeding those negotiated in the agreement. Based on that

subsample, we calculate industry-level average wages paid to workers in bargaining-covered firms in a given year. Because bargaining is forward-looking, bargaining rounds usually last 2 years and our goal is to use realized wages to proxy for wages that the firm offers to new hires today, we define the industry-based bargaining-induced wage level in year t using realized wages in year t+1.

As an alternative to the industry-level approach, we create an analogous measure based on firms' occupational structure. We first create occupation-level bargaining-induced wages by using worker-level administrative wage records and limiting the sample to workers employed in firms that are bound by industry-wide wage agreements and do not pay wages exceeding those negotiated in the agreement. We then merge-in these occupation-level average wages to firm-occupation-year-level data using information on each firm's occupational structure. Finally, we collapse the occupational-bargaining-induced wage level variable for each firm-year by taking the weighted average of occupation-level wages with weights equal to share of employees in a given occupation. Following our approach for the industry-level measure, we use realized wages in year t+1 to create an occupation-based bargaining-induced wage level in year t.

Table 5 regresses the declarations of labor constraints and a firm's own wage level on the two measures of bargaining-induced wages. In columns 1 and 4, the sample includes all firms for which industry-level wages are available,[6] because even a firm that does not follow a collective bargaining agreement is affected when bargaining induces higher wages in the local labor market. Column 1 demonstrates that when collective bargaining in a given industry pushes wages higher in a given year, firms in that industry are less likely to be labor constrained overall. Interestingly, in the subsample of firms that declare that they are labor constrained (column 2), there is no relationship between a firm's own wage and central-bargaining induced level of wages. In the sample of firms that do not report labor constraints, however, the relationship is positive and statistically significant at 10% level (column 3). These results suggest that when firms increase wages in response to quasi-exogenous increases in wages in their respective labor market driven by national-level bargaining, they can avoid labor constraints. Firms reporting labor constraints are the ones that fail to adjust their wages to this quasi-exogenous variation.

Given the challenges with determining the applicable level of bargaining, we provide results for an alternative approach based on firms' occupational structure in columns 4 to 6. Column 4 shows that when central bargaining induces wages to be high in certain occupations, firms that

[6]Due to data confidentiality rules, industry-year aggregates must be based on at least 20 observations, which precludes us from computing them for small number of industries with less than 20 firms in our data.

employ relatively many workers in those occupations are less likely to be labor constrained. Again, we document that firms that are labor constrained are not responding with their own wages to changes in bargaining-induced wage level (column 5), while firms that do not have labor constraints problems display a positive and significant response (column 6). All these results support the basic wage-related economic mechanism behind the labor constraints phenomenon: when a quasi-exogenous increase in wages in firm's environment occurs, and the firm follows by increasing their own wages, their labor constraints are alleviated.

7 Labor Constraints and the Accuracy of Firms' Beliefs

If paying higher wages alleviates labor constraints, why do firms not increase wages earlier to avoid the problem? We argue that this is at least partly due to delayed and imperfect price discovery in labor markets. Firms are slow to increase wages when shocks that increase the equilibrium wage level occur in other parts of the economy and when their beliefs about equilibrium wage level are least informative.

7.1 Price Discovery in Financial Markets and Labor Markets

Financial markets are usually quite successful at facilitating price discovery of various assets, even though the literature debates the extent to which this is influenced by various market actors or characteristics (Barclay and Hendershott, 2003; Brogaard, Hendershott and Riordan, 2014). From the perspective of an investor interested in buying shares in a liquid public firm, the current market price is almost a perfect predictor of the price at which the transaction can be completed. From the perspective of a power plant that purchases coal to be used in electricity generation, the existence of a publicly observable coal price index significantly narrows down the set of prices that the power plant might pay when buying coal from their supplier. Even though the price paid to the specific supplier for a physical delivery of a given amount of coal will likely differ from the Newcastle coal futures price, the difference is largely predictable and the time variation in the coal index explains large part of time variation in the prices actually paid by the plant.

There are examples of financial markets in which there is more uncertainty about the current market price. Some publicly traded assets with a well-defined price process, e.g., illiquid corporate bonds, may trade very infrequently and their stale prices based on transactions several days ago

may be uninformative about the price at which they can be bought today. In over-the-counter markets there may be no easily observable price process. Many times, however, these markets involve a homogeneous asset traded by a well-defined and relatively small set of participants (e.g., investment banks trading currency swaps for specific currencies) and direct communication between participants facilitates price discovery.

Labor markets are very different in that regard. There is no publicly observable and universally applicable price process, the object of transaction – labor – is not homogeneous, and there are large and diverse groups of buyers and sellers, i.e., firms and workers. While some statistics, e.g., monthly average wages in the economy, are provided by public agencies (such as the Bureau of Labor Statistics in the US), they are published with significant delay and group workers in coarse geographic and occupational categories, which are of limited use to firms that are trying to hire new workers of a particular type and in a particular place. Each labor contract involves a worker with a given level of education, experience, skills, and expectations, as well as a firm in a given industry, specific financial positions, and prospects. Each firm can hire multiple workers, and each worker can work for different firms, possibly for a different wage that is set taking into account also non-pecuniary characteristics of employment. All these factors mean that determining the appropriate level of wages for a given vacancy at a specific point in time is complicated.

Yet, wages have to be and are determined: most vacancies get filled and most workers find jobs. In most cases firms post wages, i.e., make specific wage offers to workers (Hall and Krueger, 2012). Sometimes wages are negotiated, but negotiations usually happen only at a later stage of the recruitment process and take a form of workers responding to firms' initial offers. In any case, firms need to have beliefs about the wage at which they can hire a worker, and the accuracy of these beliefs may determine how easy it is to fill a vacancy.

How do firms form their beliefs? The key sources of information involve a firm's existing compensation policy, feedback from the recruiting process, information from similar firms, and general wage and macroeconomic news. If an existing worker earns \$15 per hour, then it is probably reasonable to expect that another similar worker can be hired for \$15 per hour. The beliefs may be updated when existing workers demand higher compensation, citing higher outside offers, or when candidates refuse the job offer citing too low wages. Such feedback allows firms to adjust their beliefs and offer wages at the market level, but the central difficulty faced by the firm is separating information from noise. When a job candidate turns down the offer citing higher wages at another firm, is it a signal about a true increase in equilibrium market wage, or is it due to idiosyncratic

factors and contains little information about the wage that will be accepted by another candidate? If the feedback process is particularly noisy and slow, firms' beliefs about market-level wages may be inaccurate.

In that context, labor constraints can be interpreted as a consequence of imperfect or slow price discovery in labor markets, or – when one focuses on the buyer side – imperfect and slow updating of price beliefs by firms. If so, labor constraints should be most severe in settings in which firms' beliefs about wages are most likely to be inaccurate.

7.2 Shocks in Other Parts of The Economy

Firms may be particularly slow to update their beliefs in response to shocks to the equilibrium level of wages when these shocks originate in other parts of the economy. Suppose that due to an industry-specific technology or demand shock, the metal manufacturing industry increases demand for labor. Firms within the metal industry will be relatively well informed about that change and will quickly adjust wages, understanding that if they want to attract a higher number of workers they need to offer more than the previous equilibrium level of wages. Increasing wages attract workers who previously worked in other parts of the economy, e.g., in construction. If the metal industry in a given local area is prominent enough, then higher wages in the metal industry increase the overall market-clearing level of wages in other industries as well. Yet, firms in other industries may only learn that when they face more and more difficulties in recruiting new workers at an old level of wages – through labor constraints.

We investigate this possibility in Table 6 by exploring the evolution of labor constraints declarations and wages around variation in the bargaining-induced level of wages in other industries. The dependent variable is the level of wages (column 1) or firm's labor constraints declaration (columns 2 to 5) at time t, while the independent variables are measured at t, t-1, and t-2, and hence the regressions reveal if firms' wage and labor constraints responses are immediate or delayed. Column 1 demonstrates that a higher level of wages in other industries does not translate to a contemporaneous increase in the wage level, but two years later wages do significantly increase. Thus, a quasi-exogenous increase in wages in other parts of the economy is transmitted to firms' own wages with a delay.

Columns 2 to 5 analyze how firms' labor constraints declarations respond to quasi-exogenous variation in wages in other industries. There is no contemporaneous response, consistent with

worker flows to other industries taking some time. One year later, though, firms in other industries pay higher wages but a focal firm has not adjusted its wage level (column 1), which creates a significant and positive labor constraints response (column 3). One year later firms increase wages (column 1) and labor constraints are resolved (column 4).

We note that while specifications in columns 1 and 5, which include all lags of independent variable in one specifications, seem most appropriate, using such a specification for labor constraints may create spurious dynamics in coefficients. This is because labor constraints are only observed every two years, which is as if we dropped every second observation from the full sample. With positive autocorrelation of wages in other industries and mean-reversion in labor constraints declaration, this may bias the regression coefficients by decreasing the coefficient for the contemporaneous shock and increasing the coefficient for the first lag. Thus, while for completeness we report this specification in column 5, we believe it is more appropriate to rely on coefficients in columns 2 to 4.

The results in Table 6 are consistent with imperfect and delayed information about changing market wages being a key factor behind labor constraints. Firms that face wage increases occurring in other parts of the economy initially do not adjust their wage policies, likely because their beliefs about prevailing market wages did not change. Gradually, however, migration of workers across industries and labor markets leads to difficulties in attracting and retaining employees, and makes firms more likely to report labor constraints. Firms respond to these difficulties by increasing wages, which then alleviates the constraints. The entire process, however, lasts up to two years.

7.3 Market Synchronicity

The delayed labor constraints occurrence and even further delayed wage response is consistent with gradual learning and lack of information being a driving factor. Yet, one can also argue that other reasons, such as institutional rigidity, may explain why firms react to shocks occurring elsewhere with a delay. To lend more support to the interpretation that accuracy of beliefs is an important determinant of labor constraints, we analyze if labor constraints are more pronounced in labor markets that are less synchronized with the whole economy.

Our idea is motivated by the market microstructure literature, which argues that stock prices that have the highest firm-specific variance and lowest correlation with the aggregate market are more informative about firms' fundamentals (Roll, 1988; Durnev et al., 2003). If one does not

observe the stock price of equities with high firm-specific variance and low correlation with the market, it is difficult to have accurate beliefs about the prevailing stock price. In our context, we define synchronicity as the temporal correlation of the average level of wage in a given county/district and the average wage in the entire German economy. High correlation with the national labor market means that the equilibrium wage level in a given local area is relatively easy to determine, as the national-level information is informative and can be used to form accurate beliefs. In places where synchronicity is low, firms must rely mostly on their local experience, which may be more noisy.

Firms' beliefs about equilibrium wages are more likely to be accurate in areas with high synchronicity, which should make labor constraints less prevalent. Table 7 analyzes the link between labor constraints declarations and labor market synchronicity in the data. Consistent with the role of information being an important determinant of labor constraints, we demonstrate that firms are less likely to report labor constraints in areas with high synchronicity. This is true both when using a continuous measure of synchronicity, and a binary indicator for markets with above-median degree of synchronicity. We note that this effect may be driven not just by firms' beliefs being more accurate, but also by workers' beliefs: if all the agents in a given market are better informed, successful job matches are more likely to occur, and labor constraints are less likely to arise. In any case, the results support the importance of the accuracy of beliefs in avoiding labor constraints.

7.4 Recruitment in Core and Peripheral Occupations

An alternative approach to analyze the role of belief accuracy is inspired by the distinction between informed traders and noise traders, which has been long established in the finance literature (Kyle, 1985; Glosten and Milgrom, 1985). While in financial models all traders observe the current market price but differ in how much information about an asset's fundamentals they have, in our setting being informed means having a more accurate belief about the prevailing market wage, while being a noise trader means having a belief that may significantly deviate from the true market wage. A firm may be an informed trader or a noise trader depending on whom they hire. When the firm is hiring workers in occupations that are strongly represented in the firm's existing workforce (core occupations), the firm's beliefs about the prevailing market wage are likely to be more accurate. On the other hand, if the firm is hiring workers in peripheral occupations, with a limited representation in the current workforce, it is likely to be uninformed. For example, a construction

company is likely better informed about the equilibrium wage level for machine operators, as they employ many of them, relatively to salaries of marketing specialists, as they only have one on staff.

Table 8 analyzes the part of the SE data that describes firms' experiences with the last recruited worker. The key independent variable is the share of workers in the firm's current workforce that belong to the same occupational group. The value of this variable is high for occupational groups that are widely represented in a firm's existing workforce, and hence it is a continuous measure of the differences between core and peripheral occupations. Our specifications control for industry-by-year fixed effects, occupational group-by-year fixed effects, state, as well as continuous measures of firm size and hiring intensity in a particular occupational group.

Hiring in occupations that are more widely represented in the current workforce is associated with lower recruiting difficulties in general (column 1) and the difference is driven particularly by the wage setting process: while the overall search lasts equally long (column 2) and applicant characteristics are not differentially altered (column 5), the firm hiring in core occupations is less likely to have their initial wage offer refused (column 3) and less likely to have to pay more than they initially planned (column 4). This is not because the firm is more likely to engage in negotiations with candidates and more flexible in their wage setting practice: wage negotiations are actually less likely to occur for firms hiring in core occupations (column 6). These results are consistent with firms being more informed about the prevailing market wage in their core occupations, and thus experiencing lower labor constraints.

8 Discussion

Our findings imply that labor constraints are an important concern, both for corporations and policy makers. While the phenomenon may have many causes, the one channel that we highlight – imperfect information – can be addressed with more active labor market monitoring by private enterprises and by more comprehensive information activity of public labor market institutions.

If this problem is important, then given the increasing importance of labor constraints we should see entrepreneurial efforts to provide high-accuracy real-time labor market data, which may help firms better determine their wage beliefs. Consistent with that prediction, we do observe a recent rise in salary benchmarking, using both proprietary data and open online data (Cullen, Li and Perez-Truglia, 2022; Payscale, 2023). In addition, a number of new companies, such as Lightcast (formerly Burning Glass), Revelio Labs, and Visier, are combining insights from job

postings, government publications, social media and other sources to capture labor market trends by occupation, education, and industry. An increasing number of firms purchases these data for external benchmarking and to inform staffing and pay strategies.

Despite these developments, more comprehensive reporting by public statistical agencies might also be a welcome change. Publicly provided information would help smaller firms that do not purchase private data on labor markets to be better aligned with changing labor market realities. Government regulation can also play an additional role by mandating pay transparency across firms. Indeed, a recent wave of new legislation has introduced requirements for firms to disclose pay ranges in job postings in a number of European countries and US states (Cullen, 2024). In combination with the emergence of labor market data providers, these laws can help disseminate levels and changes in market wages by skill profile and geography.

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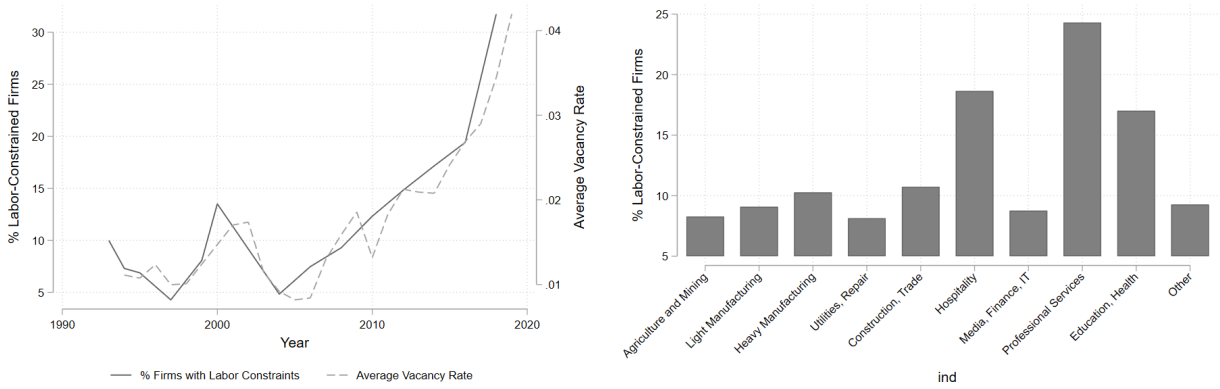
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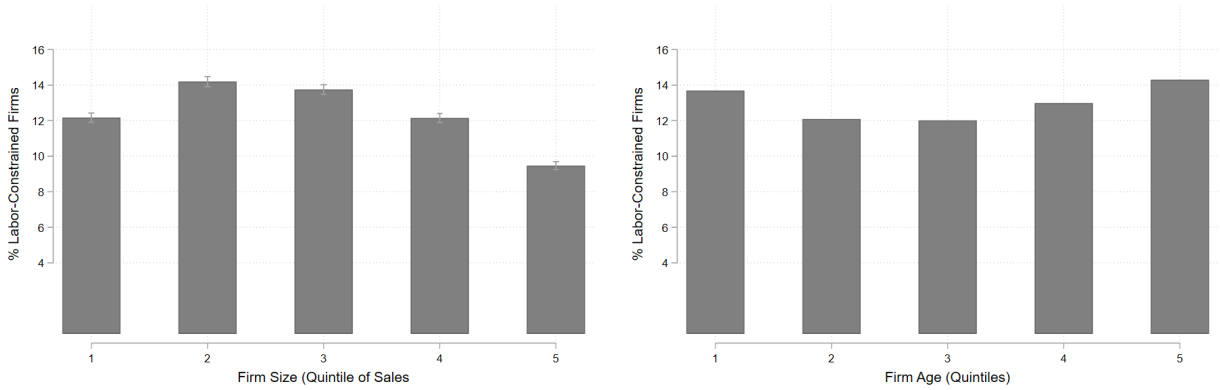
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Figure 1: Labor Constraints by Time and Industry



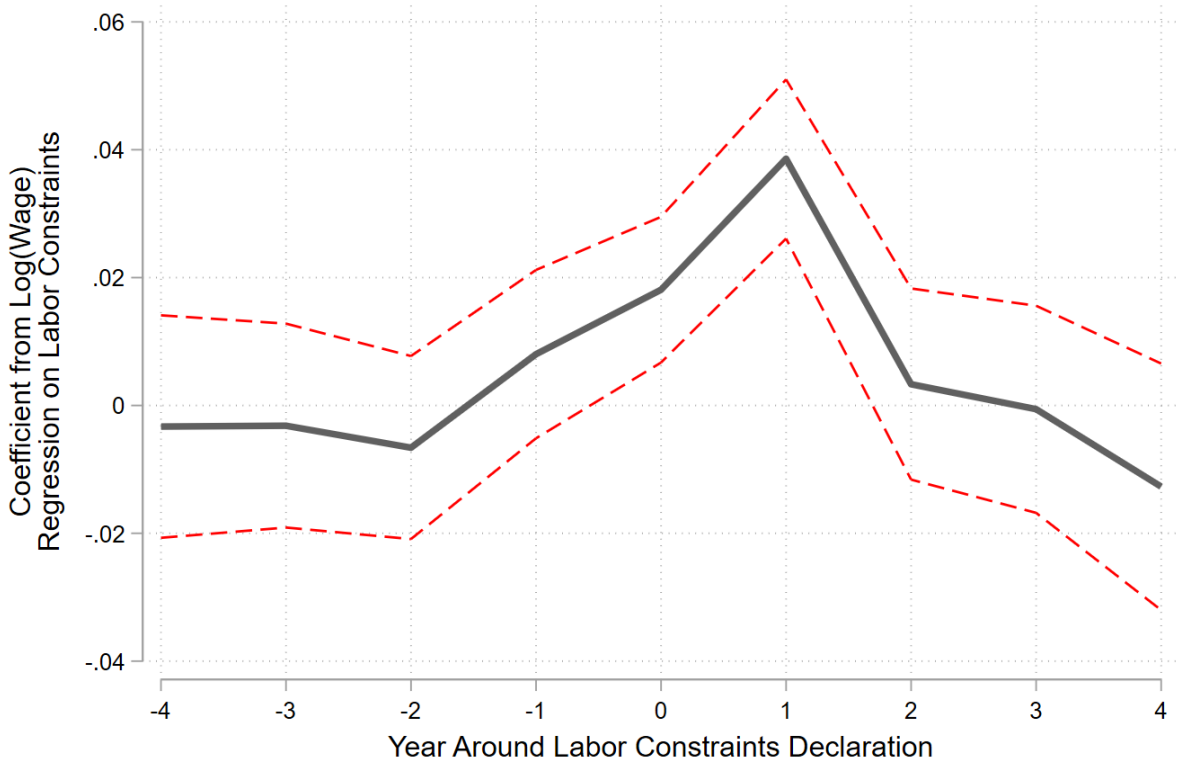
The left panel shows the evolution of the share of firms reporting labor constraints and of the average vacancy rates over time (EP data). Labor constraints are reported only in selected waves of the survey, often every two years. The right panel shows the average share of firms reporting labor constraints in different industries. Industry codes are 1-digit codes based on W08 codes of the German Employment Agency, which are close to International Standard Industrial Classification (ISIC) codes.

Figure 2: Labor Constraints by Firm Size and Age



The left panel shows the share of firms reporting labor constraints by quintile of firm size, computed based on total sales. The average sales level in each quintile in millions of EUR is 0.7, 2.2, 5.7, 18.8, and 737. The right panel shows the average share of firms reporting labor constraints by quintiles of firm age. The average age of firm in each quintile in years is: 4.3, 10.8, 18.1, 25.4, 36.0. Both figures are based on EP data.

Figure 3: Evolution of Wages around Labor Constraints Declarations



The solid line represents the coefficients from regressing the logarithm of average wages for new hires on respective lags and leads of labor constraints declarations by firms. For example, the value for t=-4 represents the coefficient from regressing the level of wages in year t on the 4th lead of labor constraints declaration and hence the coefficient represents level of wages 4 years before the firm declared labor constraints. Each regression includes establishment fixed effect as well as state-by-year FE and industry-by-year FE. Wages are winsorized at 1st and 99th percentile. Dashed lines represent 95% confidence intervals.

Table 1: Summary Statistics

The sample for the Vacancy Survey (SE) contains 232,696 firm-year observations. Firms that declare that they have been searching for worker in the last 12 months are asked questions about search duration, search difficulties, and wage offered related to their last completed worker search. Sample size varies because not all questions were asked in all waves of the survey. Labor constraints and financial constraints are declarations that firm sales in the near future would be higher if not for these constraints. There are 77,330 firm-year observations in the IAB Establishment Panel sample filtered on the availability of employment and labor constraints data. Sales are missing for part of the sample; sales growth is winsorized at 1st and 99th percentile. For confidentiality reasons, bargaining-induced wage growth is not available for some observations belonging to industry/occupation-year cells with less than 20 observations.

	Mean	Std Dev	P5	P95	N
Vacancy Survey (SE)					
Search Difficulties	0.286	0.451	0	1	57,935
Search Duration [days]	92.6	78.5	12	245	112,570
Monthly Wage Offered [EUR]	2,367	1,040	1,030	4,400	39,641
Stopped Search	0.166	0.372	0	1	147,430
Vacancy Rate (SE)	0.029	0.194	0	0.142	232,696
Labor Constraints (SE)	0.095	0.293	0	1	232,696
Financial Constraints	0.064	0.244	0	1	232,696
% Workforce in Hired Occupation	0.179	0.257	0	0.771	46,578
Had to Pay More than Planned	0.117	0.321	0	1	57,930
IAB Establishment Panel (IAB-EP)					
Employment	261	1,059	15	1,026	77,330
Sales [EUR Million]	164	2,960	0.6	281	56,360
Sales Growth (winsorized)	0.045	0.270	-0.318	0.472	52,724
Employment Growth	-0.017	0.295	-0.268	0.223	167,989
Profitable	0.907	0.290	0	1	165,865
Incumbents Daily Wage [EUR]	76.4	28.9	42.3	128.7	77,273
New Hires Daily Wage [EUR]	51.8	28.3	42.3	128.7	77,273
Labor Constraints (IAB-EP)	0.122	0.327	0	1	77,330
Labor Constraints (shift-share)	0.134	0.114	0.017	0.379	102,887
Vacancy Rate (IAB-EP)	0.015	0.041	0	0.091	77,330
Bargaining-Induced Wage Growth	0.024	0.059	-0.054	0.122	71,648
Bargaining-Induced Oth Ind Wage Growth	0.019	0.018	-0.012	0.045	71,579

Table 2: Cross-Validation of Labor Constraints Measures

Results in columns 1 to 3 are estimated using data from the Vacancy Survey (repeated cross-section of firms); columns 4 to 7 are estimated using data from the IAB Establishment Panel (panel of firm-year observations). The main independent variable in columns 1 to 5 is firms' declaration of labor constraints, which in columns 1 to 3 represents a declaration that lack of suitable workers is an impediment to firm's operations, while in columns 4 to 5 a declaration that the firm expects problems with labor shortages. In columns 6 and 7, the main independent variable is the shift-share measure of labor constraints based on firms' occupational structure and occupation-level national constraints intensity. The dependent variables are logarithm of the length of last worker search in days (column 1), an indicator for having failed a worker search in the last 12 months (column 2), vacancy rate (columns 3 to 5), defined as the number of reported vacancies divided by the number of workers, and the firm's labor constraints declaration (columns 6 and 7). Each column includes local area-by-year FE, industry-by-year FE and firm size FE. Column 1 further includes occupation-by-year FE, where occupation refers to the occupation of the workers in the last successful search. while Columns 5 and 7 include establishment FE. Local area is defined as state in columns 1 to 3 and commuting zone in columns 4 to 7. Robust standard errors (columns 1 to 3) and standard errors clustered by establishment (columns 4 to 7) are reported in parentheses. *** represents 1% significance.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Search Duration	Failed Search Last 12M	Vacancy Rate	Vacancy Rate		Labor Constraints	
Labor Constraints (SE)	0.294***	0.494***	0.077***				
	(0.013)	(0.005)	(0.001)				
Labor Constraints (EP)				0.014***	0.004***		
				(0.001)	(0.001)		
Labor Constraints (shift-share)						0.827***	0.672***
						(0.044)	(0.055)
N	51,082	104,373	108,176	77,330	77,330	77,310	77,310
Dataset	Vacancy Survey (SE)			IAB-Establishment Panel (EP)			
Baseline FE	✓	✓	✓	✓	✓	✓	✓
Plant FE					✓		✓

Table 3: Labor Constraints and Real Outcomes

All regressions use data from IAB Establishment Panel and the observation unit is establishment-year. The main independent variables are firms' own declaration of labor constraints and the shift-share measure of labor constraints based on establishments' occupational structure in a given year and occupation-level measures of labor shortages for the whole economy. The dependent variables are relative changes in the total number of employees, logarithm of capital expenditures in EUR, relative sales growth at t+1, and an indicator for firm's being profitable at t+1. Each column includes establishment FE, commuting zone-by-year FE, industry-by-year FE and firm size FE. Standard errors are clustered by establishment. *** represents 1% significance, ** - 5%, * - 10%.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	%ΔEmployment		Log(CAPEX)		%ΔSales [t+1]		Profitable [t+1]	
Labor Constraints	0.009**		0.241***		0.018***		0.011***	
	(0.004)		(0.078)		(0.006)		(0.004)	
Labor Constraints (shift-share)		-0.115**		0.621		-0.101*		-0.064*
		(0.053)		(0.730)		(0.057)		(0.038)
N	77,992	78,218	76,800	76,780	57,763	57,852	58,217	58,319
Baseline FE	✓	✓	✓	✓	✓	✓	✓	✓
Plant FE	✓	✓	✓	✓	✓	✓	✓	✓

Table 4: Labor Constraints and Initial Pay Level

Columns 1 to 4 are estimated using data from IAB Establishment Panel (panel of firm-year observations), while columns 5 and 6 use data from the Vacancy Survey (repeated cross-section of firms). The main independent variable is the logarithm of average wages in the previous year. The dependent variables are declarations of labor constraints, i.e.. that the firm expects problems with labor shortages (columns 1 to 3) or that the lack of suitable workers is an impediment to firm's operations (column 5), and vacancy rate (columns 4 and 6), defined as the number of reported vacancies divided by the number of workers. Each column includes commuting zone-by-year FE, industry-by-year FE. Columns 2 to 6 further include firm size FE. Column 3 includes additional controls: firm age, existence of workers' council, profit situation, sales volume. Standard errors are clustered by establishment. *** represents 1% significance.

	(1)	(2)	(3)	(4)	(5)	(6)
	Labor Constraints			Vacancy Rate	Labor Constraints	Vacancy Rate
Log(Wage) [t-1]	-0.029***	-0.051***	-0.046***	-0.007***	-0.067***	-0.007***
	(0.005)	(0.006)	(0.006)	(0.001)	(0.003)	(0.001)
N	77,330	77,330	71,981	163,364	99,334	99,334
Dataset	IAB Establishment Panel				Vacancy Survey (SE)	
Baseline FE	✓	✓	✓	✓	✓	✓
Size		✓	✓	✓	✓	✓
Oth Controls			✓			

Table 5: Central Bargaining-Induced Wage Level and Labor Constraints

All specifications are estimated in the IAB Establishment Panel with the unit of observation being establishment-year. The dependent variable in columns 1 and 4 is firms' declaration of labor constraints, i.e., that the firm expects problems with labor shortages. The dependent variable in columns 2, 3, 5, and 6 is the logarithm of establishment-level average wages. Independent variables are logarithms of bargaining-induced wage levels for a given establishment based on its industry (columns 1 to 3) or occupational structure (columns 4 to 6). Establishment FE and fixed effects for commuting zone-by-year and for firm size as well as controls for profitability, existence of workers council, and firm age are included in all columns. Columns 4 to 6 include fixed effects for industry-by-year. The bargaining-induced levels of wages are winsorized at 2.5 and 97.5 percentile. Standard errors are clustered by industry in columns 1–3, and by establishment in columns 4–6. *** represents 1% statistical significance, ** - 5%, * - 10%.

	(1)	(2)	(3)	(4)	(5)	(6)
	Labor Constraints	Log(Wage)		Labor Constraints	Log(Wage)	
Bargaining-Induced Wage (Industry)	-0.0566**	-0.0630	0.0494*			
	(0.0249)	(0.0717)	(0.0285)			
Bargaining-Induced Wage (Occupation)				-0.0332**	0.0149	0.0758***
				(0.0143)	(0.0401)	(0.0105)
N	43,301	2,797	37,288	62,045	3,067	54,321
Sample	Full	Cons	Uncons	Full	Cons	Uncons
CZ-Year, Size FE	✓	✓	✓	✓	✓	✓
Plant FE	✓	✓	✓	✓	✓	✓
Other Controls	✓	✓	✓	✓	✓	✓

Table 6: Labor Constraints and Wage Shocks in Other Parts of the Economy

All specifications are estimated in the IAB Establishment Panel with the unit of observation being establishment-year. The dependent variable is the logarithm of establishment average wages (column 1) and a firm's declaration of labor constraints, i.e., that the firm expects problems with labor shortages (columns 2 to 5). Independent variables are logarithms of the central bargaining-induced level of wages in other industries, calculated using local area industrial composition and industry-level bargaining-induced wage level. The independent variables represent values contemporaneous to the outcome variable, first annual lag, and second lag. All specifications include establishment FE, commuting zone-year FE, industry-by-year FE, and firm size FE. Standard errors are two-way clustered by district and industry. *** represents 1% statistical significance, ** - 5%.

Coefficient on Bargaining-Induced Local Wage in Oth Industries:	(1) Log(Wage)	(2)	(3)	(4)	(5)
		Labor Constraints			
[T]	0.008	-0.016			-0.148***
	(0.012)	(0.034)			(0.039)
[T-1]	0.010		0.106**		0.186***
	(0.014)		(0.046)		(0.069)
[T-2]	0.025**			0.024	-0.043
	(0.013)			(0.070)	(0.097)
N	98,351	60,740	50,580	42,731	41,508
CZ-Year, Ind-Year, Size FE	✓	✓	✓	✓	✓
Plant FE	✓	✓	✓	✓	✓
Other Controls	✓	✓	✓	✓	✓

Table 7: Labor Constraints and Labor Market Synchronicity

All specifications are estimated in the IAB Establishment Panel with the unit of observation being establishment-year. Dependent variable is firm's declaration of labor constraints, i.e., that the firm expects problems with labor shortages. Independent variables are measure of local labor market synchronicity with national market and an indicator for above-median synchronicity. The continuous measure is the temporal correlation between average wage changes in a given district and in German economy as a whole. All specifications include industry-by-year and firm size fixed effects. Columns 2 and 4 further control for establishment's log wage, existence of worker council, probability, and firm age. Standard errors are two-way clustered by district and industry. *** represents 1% statistical significance, ** - 5%.

	(1)	(2)	(3)	(4)
	Labor Constraints		Labor Constraints	
Synchronicity of Local Labor Market	-0.0184**	-0.0240***		
	(0.0081)	(0.0083)		
High Synchronicity			-0.00630**	-0.00805**
			(0.00297)	(0.00315)
N	99,792	99,792	99,792	93,380
Ind-Year, Size FE	✓	✓	✓	✓
Other Controls		✓		✓

Table 8: Recruitment of Core and Peripheral Occupations

All specifications are estimated in the Vacancy Survey data with the unit of observation being each establishment's last conducted worker search. The dependent variables are an indicator for experiencing any hiring difficulties, the logarithm of the search duration in days, and binary indicators for the firm declaring that during the process the applicant has refused a wage offer; that the final pay was higher that the firm initially planned, that the hired candidate differs from initial expectations along dimensions such as experience or education, and that the final wage was negotiated. The independent variable is the share of the firm's existing workforce in the same occupation as the occupation of the conducted search. All columns include fixed effects for state, industry-by-year, and occupation-by-year, as well as the logarithm of total number of workers and the hiring rate in a given occupation (number of workers in a given occupation hired in a given year divided by the total workforce). Standard errors are clustered by occupation. *** represents 1% statistical significance, ** - 5%.

	(1) Hiring Difficulties	(2) Log(Search Duration)	(3) Applicant Refused Wage Offer	(4) Had to Pay More Than Planned	(5) Hire Differs from What Looked For	(6) Wage Negotiated
%Workforce in Hired Occupation	-0.0457***	0.0318	-0.0381***	-0.0329**	-0.0104	-0.0841***
	(0.0166)	(0.0441)	(0.0090)	(0.0133)	(0.0123)	(0.0305)
N	44,555	36,365	45,290	44,600	44,393	27,497
Fixed Effects	✓	✓	✓	✓	✓	✓
Hiring Rate	✓	✓	✓	✓	✓	✓
Workforce Size	✓	✓	✓	✓	✓	✓