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Help wanted: the drivers and implications of labour shortages

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Abstract

Labour shortages have become prevalent across advanced economies. Yet, little is known about which firms are more likely to face them and the impact they have on the labour market. We create a firm-level data set spanning 28 EU countries, 283 regions and 18 sectors, contributing to close this gap. We find that structural factors play the dominant role. Firms in regions with limited labour supply as well as innovative and fast-growing firms are particularly prone to face labour shortages. Moreover, shortages tend to aggravate at business cycle peaks. In a second stage, we empirically determine the impact of labour shortages on wages and hiring. Firms with higher shortages pay a wage growth premium to keep and attract workers, increasingly so if they face excess demand. At the same time, those are the firms that hire less than the average.

Keywords: labour shortages, tightness, matching, shift-share instrument
JEL codes: C36, E24, J20, J23, J30

Non-technical summary

Labour shortages have become increasingly prevalent in advanced economies, including Europe. Yet, little is known so far about which firms tend to face more shortages and what is the impact of such shortages on labour market outcomes.

In this paper, we contribute to closing this gap. We create a large pan-European firm-level data set on labour shortages, including firm, regional and sectoral characteristics, spanning across 28 EU countries, 283 regions and 18 sectors over the last ten years. To our knowledge, this is the most comprehensive data set analysing labour shortages with micro-level data so far. We use an indicator that captures firm-specific perceptions of labour shortage, i.e., the extent to which a firm's demand for suitable workers cannot be covered by the available labour supply at current wages and working conditions.

We conduct our analysis in two steps. First, we analyse whether labour market shortages are more related to structural factors or to business cycle fluctuations. Over the full sample, our multi-level panel regression analysis shows that structural factors are more important in explaining differences in labour shortages. Firms experience higher labour shortages if the region exhibits a lack of labour supply. This is true for quantities, such as a lower labour force participation rate or higher unemployment rates, but also applies to qualities of labour. In regions with a below-average share of highly educated people, more firms tend to have labour shortages. Similarly, sectors with higher skill requirements are associated with more firms facing labour shortages. Also, country differences play a pivotal role in explaining labour shortages across firms. Lastly, firm differences explain labour shortages. Younger, fast-growing and more innovative firms face the largest labour shortages.

Notwithstanding the importance of such structural factors, labour shortages also move with the cycle. The stronger sectoral or regional economic activity and the lower the cyclical unemployment rate, the more likely it is that the firms will face shortages of labour. Already the prospective brightening of the economic environment increases shortages, as firms anticipate cyclical improvements.

In a second step, we document the causal impact of labour shortages on the hiring decisions of firms and on wage growth. We analyse this behaviour in a panel regression framework, including a broad set of fixed effects and a shift-share instrument for our labour shortage indicator to deal

with potential endogeneity issues. We find that labour shortages, an expression of tightness, lack of supply, but also inefficient matching, have a bearing on employment (at least under some circumstance) and on wage growth. Applying a Phillips curve-like specification at firm-level, we find that firms with higher labour shortages across time pay a wage growth premium to keep incumbent and attract new workers. The wage growth is topped up further when the firm is strongly growing or produces in a particularly labour-intensive way. When running the analysis on aggregated data at regional level, our results are robust.

Employment growth is on average not significantly impacted by labour shortages. This seems to reflect two countervailing forces. On the one hand, part of the labour shortages are successfully addressed by the firm through new hires. On the other hand, some parts of the intended hiring cannot be satisfied (matching inefficiency, insufficient labour supply). This becomes clearer when looking at fast growing firms. While they are able to increase employment, labour shortages hold them back in satisfying overall hiring intentions. The higher the perceived shortages, the more turns the firm-specific hiring towards zero.

The important structural dimension of labour shortages that we find in our paper has an implication for national structural policies. Designing policies that increase the quality of labour (e.g. upskilling) and the quantity of labour (e.g. tapping inactive workers and attracting inward migration) has the potential to reduce labour shortages going forward. In the absence of such policies, and in the face of an anyway ageing population, labour shortages have the potential to increase further, possibly with a rising share of firms paying a wage premium. This, in turn, if broad enough, could have an implication for aggregate wage growth in the economy, to be monitored then also by other policies, including monetary policy.

In terms of future research, our data set opens the possibility to study a range of related questions, including how labour shortages potentially affect other dimensions of firm activity, such as their innovation capacities or productivity.

1 Introduction

Labour shortages have become a prevalent feature in advanced economies' labour markets. They reflect the extent to which a firm's demand for suitable workers cannot be covered by the available labour supply at current wages and working conditions. Accordingly, the concept of labour shortages is linked to, but goes beyond the concept of labour market tightness for two reasons.

First, labour market tightness tends to be more geared toward the labour demand perspective. Labour market tightness is a key concept in standard search and matching models (Mortensen and Pissarides, 1994), in which it is commonly defined as the ratio of vacancies to unemployment. This captures the explicit labour demand, i.e. job posting, and a narrowly defined supply dimension (the unemployment rate). Labour shortages, in turn, capture a stronger supply dimension. Among others, they include the notion of labour force developments (nationals and migration), demographic challenges, but also the quality of the labour supplied (i.e. education and vocational training).

There is a second dimension in which labour shortages go beyond labour market tightness. They better capture a notion of mismatch between demand and supply in the labour market. Together with the tightness of labour markets, matching efficiencies determine the job finding rate and thus affect hiring and wages (Petrongolo and Pissarides, 2001). Firms' perceived labour shortages are a gauge of matching inefficiencies, as they also cover cases in which firms fill a vacant position, but with a match that is sub-optimal. It also captures temporary discouragement, in that firms indicate they face a shortage of labour but still they do not post a vacancy as they judge they currently cannot find a suitable candidate in the pool of available workers.

Despite the usefulness of labour shortages as a measure to gauge the state of the labour market, given the scarcity of data, little is known about which firms are more likely to face shortages and which consequences they have. The existing literature has focused on single countries, sectors and specific years so far.

We address this shortcoming by building a unique data set across 28 EU countries, 283 regions, and 18 sectors. This unique firm-level database on labour shortages combines firm-characteristics such as employment and wage developments, with information about the sector-, region- and country-specific environment that the firm is operating in. We use the survey question on the degree of labour shortages as asked by the ECB Survey on the Access to Finance of Enterprises and

match those firms with the Bureau van Dijk (ORBIS) balance sheet data. This database is then augmented by regional and sectoral Eurostat data.

We contribute to the literature along two avenues. First, we describe the differences in labour shortages between regions, sectors and firms. What kind of firms tend to face higher labour shortages? Do these shortages relate more to structural factors, like regional labour supply and country-specific features, and how much are they moving with the business cycle? Second, we analyse the implications of said shortages. Applying an instrumental variable approach, we study their causal effects on key labour market outcomes, notably wage and employment growth.

The first part of our analysis adds to the few existing micro-data studies on the reasons of labour shortages. Only very scarce and country-specific studies have so far analysed this labour market aspect. Haskel and Martin (1993, 2001) use UK firm-level data and point to the importance of external factors, like the unemployment rate and house prices, and internal factors, like flexibility and automation. They find that establishments using advanced technology in the production process are more prone to labour shortages and argue that skill shortages are largely structural, requiring a permanent upskilling policy by national policies. Holzer (1994) gauges the determinants of vacancy rates, reverting to the narrower definition of shortages, looking only at jobs actually posted. For US firm-level data, he establishes the importance of labour supply (unemployment), the relevance of skill levels and the role of high turnover firms in their impact on labour shortages. Horbach (2014) focuses on the German environmental sector and finds that innovative firms are most likely to exhibit shortages. Yet, not always is the shortage limited to skilled staff, but depending on the specific sub-sector, the shortage might as well be that employees having no professional training. Green et al. (1998) show that labour shortages are in fact interpreted rather broadly, covering both the quantity and the quality dimension. Employers do not limit labour shortage to the number of staff missing in the production of products or services, but that may equate shortages with internal skill deficiencies (Healy et al., 2015; Green et al., 1998).

Building on the country-specific literature and the relevant factors found in the past, we generalise the findings using our European cross-sector sample. In addition, we group factors and find that labour shortages are mainly explained by slow-moving structural factors. Firms identify higher labour shortage if the region exhibits a lack of labour supply. This is true for quantities, such as a

lower labour force participation rate or lower unemployment rates, but also applies to the quality of labour. In regions with a below-average share of highly educated people, more firms tend to have labour shortages. Similarly, firms in sectors with higher skill requirements tend to identify more labour shortages. With country fixed effects, specific indicators of countries' structural difference (unemployment benefits, tax wedge, active labour market policies) turn insignificant. Yet, the country fixed effects are significantly different and high, pointing to country institutions as a structural reason for labour shortages. Lastly, firm differences correlate with labour shortages. Younger, faster-growing and more innovative firms face the largest labour shortages.

Notwithstanding the importance of structural factors, labour shortages (not surprisingly as they also capture to some extent labour market tightness) move with the business cycle. More buoyant sectoral or regional activity, a lower cyclical unemployment rate tends to push up labour shortages.

The second part of our study can be related to the existing literature on the wage Phillips curve (e.g. Gali (2011) or for a broader overview Nickel et al. (2020)). Most of the literature is using macro-level data with tightness indicators most often being either the unemployment rate (Phillips, 1958) or a version of the unemployment gap (Gordon, 1997). More recently, studies argue that focusing on (the) unemployment (gap) alone is not sufficient. First, there are well-known measurement issues with the unobservable NAIRU. Second, the unemployment rate can overestimate the degree of labour market slack, since the long-term unemployed exert significantly less wage pressures than other unemployed (Krueger et al., 2014). By contrast, the unemployment rate neither includes hidden unemployment (the marginally attached not active in the labour force), nor is it controlling for search intensity of firms and households. With that line of argument in mind, an alternative approach is motivated by Mortensen and Pissarides (1994) search and matching models and therefore links the unemployment rate to job openings to assess the labor market tightness. Accordingly, such work applies the vacancy, the vacancy-to-unemployment ratio or a measure of labour shortages to proxy slack (Domash and Summers, 2022; Barnichon et al., 2021). Given the aggregation bias at country level, some studies look into micro data to control for search efforts of firms and households in Phillips curves' specifications (e.g. Adrjan and Lydon, 2019; Frohm, 2021; Lombardi et al., 2023). In line with this literature, we use firm-level data to unpack heterogeneity across firms, sectors and regions, and improve the analysis of causal effects of economic constraints on wage and employment

growth.

Regarding the role of labour shortages, a small number of studies analyse their impact on wages, employment and other outcomes for specific countries or sectors. In Canada, for example, companies that expect labour shortage are more likely to increase their wages (Morissette, 2022). Similarly, in Sweden, the relative labour shortages yield a much better fit in the wage Phillips curve environment, reporting a significantly positive coefficient (Frohm, 2021). Kölling (2022) and Horbach (2014) aim to capture the causal effects of labour shortages on wages in Germany by applying a two-stage control function approach and an IV regression, respectively. While Kölling (2022) only finds significantly higher wages in firms not bound by collective agreements, Horbach (2014) finds that firms in the environmental sector are more likely to pay above average if they lack skilled workers. We extend these analyses for a sample of whole Europe and various sectors and apply another instrument, arguably more exogenous and still relevant, to describe causal effects of labour shortages. The impact of labour shortages, however, extends beyond that on wages. Skill shortages and hiring problems constrain employment growth in Australia (Coelli and Wilkins, 2008) and France (Le Barbanchon et al., 2023). Similar to our approach, Le Barbanchon et al. (2023) apply a shift-share instrument to describe causal effects and find that the sensitivity of employment to recruiting difficulties is significantly stronger for labor-intensive firms and for firms with high occupation-specificity.

In line with the latest literature, our paper takes a standard Phillips curve specification complemented with productivity growth. We add a firm-specific measure of labour shortages, instrumented by a shift-share instrument to allow for causal interpretations. In addition to wage reaction, our analysis adds to the literature by reviewing the hiring response of firms from all over Europe to such labour shortages. Both wages and hiring are likely to react more to labour shortages if a firm faces stronger demand for its goods and services (here labelled as excess demand). We control for such differences.

In this second part, we find that labour shortages have a significant impact on wages and employment (the latter, however, only under some circumstances). Thus, in line with search and matching models, we find that labour shortages, an expression of tightness, limited supply, but also possibly less efficient matching, have a bearing on employment and wage growth. Applying a

Phillips curve-like specification at firm-level, we find that firms with higher labour shortages pay a wage growth premium to keep incumbent and attract new workers. Wage growth is topped up further when the firm is growing strongly or produces in a particularly labour-intensive way. When running the analysis on aggregated data at regional level, our results are robust. Employment growth is on average not significantly impacted by labour shortages. This seems to be a reflection of two countervailing forces. First, part of the labour shortages are successfully addressed by the firm through new hiring. Yet, another part cannot be satisfied due to matching inefficiency and insufficient labour supply. This becomes even clearer when looking at fast growing firms. While they are able to increase employment, labour shortages hold them back in satisfying overall hiring intentions. The higher the perceived shortages, the more turns the firm-specific hiring towards zero or becomes negative, with firms possibly replacing some labour with capital.

The paper is structured as follows. We present the unique data set in Section 2, before elaborating in turn on the two legs of our analysis. In Section 3 we explain the methodology, the results and robustness checks of our descriptive analysis of labour shortage factors. In turn, in Section 4 we cover the empirical setup, the results and robustness checks on how labour shortages impact employment and wage growth. We conclude in Section 5.

2 Data

In order to describe the drivers and implications of labour shortages we create a unique data set by combining firm-level micro data with aggregate regional and sectoral data. In particular, we merge responses from the Survey on the Access to Finance of Enterprises (SAFE), quantitative accounting data from ORBIS and regional and sectoral information from Eurostat. This data set contains information on 86,513 firms from 28 countries, 283 regions and 18 sectors over a period of 10 years. It allows us to distinguish between the cyclical and structural components of labour shortages, to describe the heterogeneities across Europe and to make causal interpretations of their impact on the economy.

2.1 Survey on the access to finance of enterprises (SAFE)

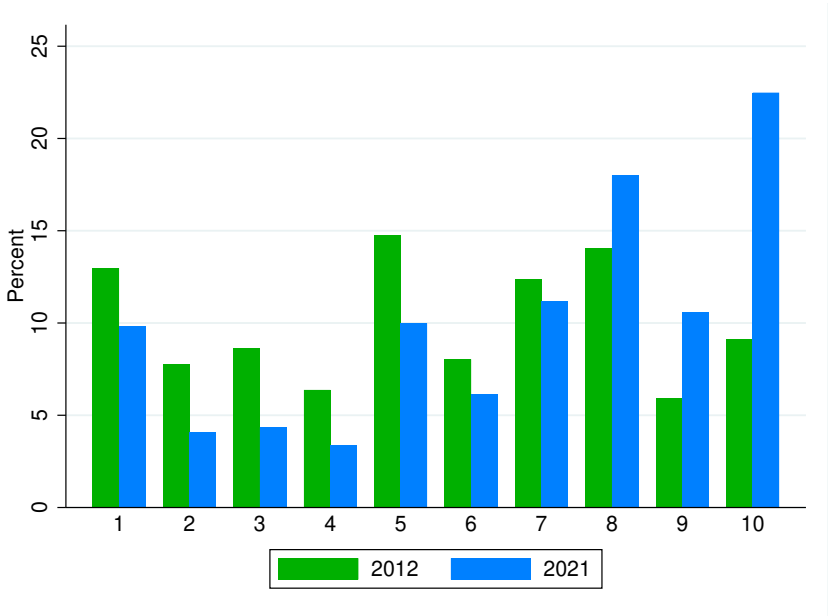
The SAFE is a biannual survey conducted on behalf of the European Central Bank (ECB) via telephone interview and online questionnaire to evaluate the financing conditions of firms. The responses are collected in March and October since 2009. The more comprehensive waves collected every October contain more than 15,000 observations from firms across all EU countries. The spring waves contain around 11,000 firms but only from the eleven largest euro area countries. The data set is constructed by randomly choosing firms from the Dun & Bradstreet business register, with the number of firms adjusted across countries, size class and economic activity to increase the accuracy of the survey. In order to match total economy representation, weights are included with regard to firm size and economic activity. To assess changes over time, the sample includes a rotating panel of enterprises, with around 62% of all firms responding at least a second time (ECB, 2022).

While the focus of the survey is on firms' financial situation and their relationship to the financial market, it also contains general information and questions about problems faced by firms. The question of interest for our analysis about labour shortages is as follows: *How important has the following problem - the availability of skilled staff or experienced managers - been for your enterprise in the past six months? [Please answer on a scale of 1-10, where 1 means it is not at all important and 10 means it is extremely important.]* This captures the firm-specific perception of a shortage of suitable employees, i.e., the extent to which a firm's demand for workers with specific skills in a specific region is not covered by the labour supply at current wages and working-conditions. Thus, it is not only a demand indicator like current or planned vacancies, but also reflects the supply of suitable workers and matching inefficiencies. Note that not only actively hiring firms answer this question (with high values) as firms can have already given up posting vacancies although they still need more workers, or they might have difficulties in finding newly required skills within their staff.

As shown by Figure 1, the responses are not equally distributed along the 10-point scale with the median being at 7. However, all values are represented. As noted in Section 1, with the economic expansion in the euro area economies, perceived labour shortages gradually increased from 2012 to 2021. In addition, the relative importance of labour shortages in comparison to other constraints faced by firms increased (see Figure A.2). Since 2017, with a short break during the COVID-19 pandemic, labour shortages have been the most relevant operational problem among European

firms. While this indicator captures the tightness in the labour market, it captures more than that, and it reflects the firm-specific situation, which may be different even for firms in the same sector and region due to differences in technology, management, amenities or other dimensions.[1]

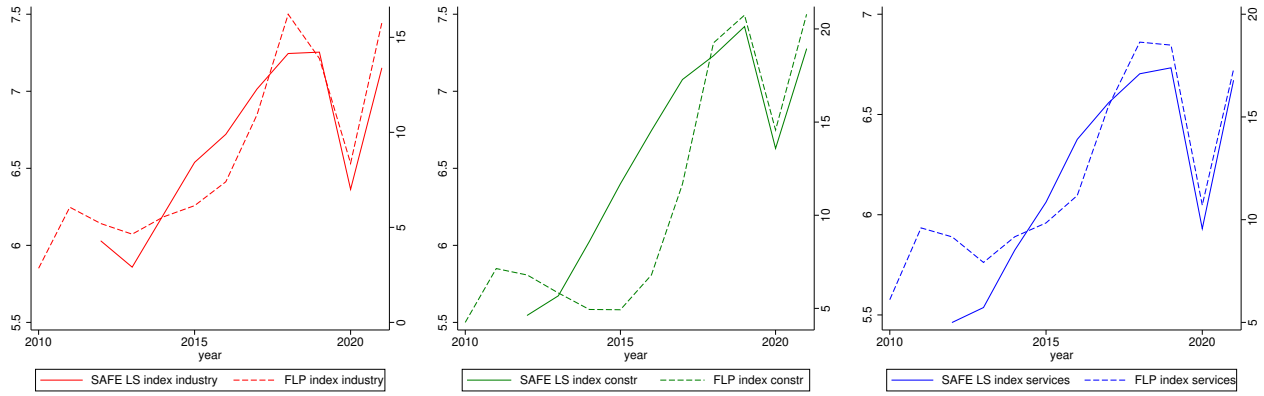
Figure 1: Labour Shortage Indicator - Distribution



The use of a scale from one to ten is an improvement compared to former surveys, where the respondents could only decide between yes and no. From 2012 onwards, it is possible to describe this continuously developing problem more accurately which captures dimensions like the urgency, the broadness or the lastingness of labour shortages. However, the interpretation of the question is still up to the respondent. To validate that the SAFE's question actually captures labour shortages, we compare the average responses to the factors limiting production index from the quarterly Business & Consumer Survey conducted by the European Commission. The index describes labour shortages per sector over time. Figure 2 shows that the weighted average response to the SAFE's labour shortage questions follows the pattern of the factors limiting production index in the industry, construction, and service sector. Hence, the data on labour shortages provided by SAFE seem to well capture the developments of the last decade.

[1]See Figure A.1 for a comparison between the vacancy-to-unemployment ratio (capturing the labour market tightness) and our labour shortage index.

Figure 2: Labour Shortage - SAFE vs FLP



Notes: Comparison of the development of the factors limiting production (FLP) index (right axis) and the weighted average labour shortage indicator in the SAFE data (left axis) for the EU.

Besides the question on the shortage of labour, we make use of several other variables asked in SAFE, like the size classes or firm expectations on sales and economic development. A detailed overview of all variables used in the econometric analysis can be found in the Appendix.

2.2 Orbis

The Orbis data set provided by the Bureau van Dijk (BvD) contains millions of annual firm data from around the world. It includes balance sheet information, profit & loss statements as well as information on the number of employees or the sector of operation over a relatively long period of time. Given problems in answering detailed accounting numbers in telephone interviews, the SAFE does not include this kind of quantitative variables. Hence, both data sets are merged with a match rate of around 85% by using the observations from the October SAFE waves (including all EU countries).[2] We use the EU waves, since the euro area waves have less observations and a smaller number of questions is asked. The analyses presented in the following chapters are, however, robust to changing the waves used in the merging process and summary statistics of the variables used are very similar. The resulting data set contains 147,149 firm-year observations from 86,513 firms

[2] Bańkowska et al. (2014) give more details about how the data can be merged, although many of the summary statistics do not apply anymore given the developments of the survey during the last eight years.

to analyse the role of labour shortages between 2012 and 2021. In line with the literature (e.g. Kalemli-Ozcan et al., 2019), we prepare and clean the information provided by Orbis by dropping bankrupt firms and wrong observations (e.g. negative employees or sales), correcting values of firms with unclear reporting units, and excluding extreme values of employment and wage growth by trimming the top and bottom 1% of each country separately (to preserve the country-specific distribution). All nominal variables are deflated by using country- and sector-specific GDP deflators.

2.3 Eurostat

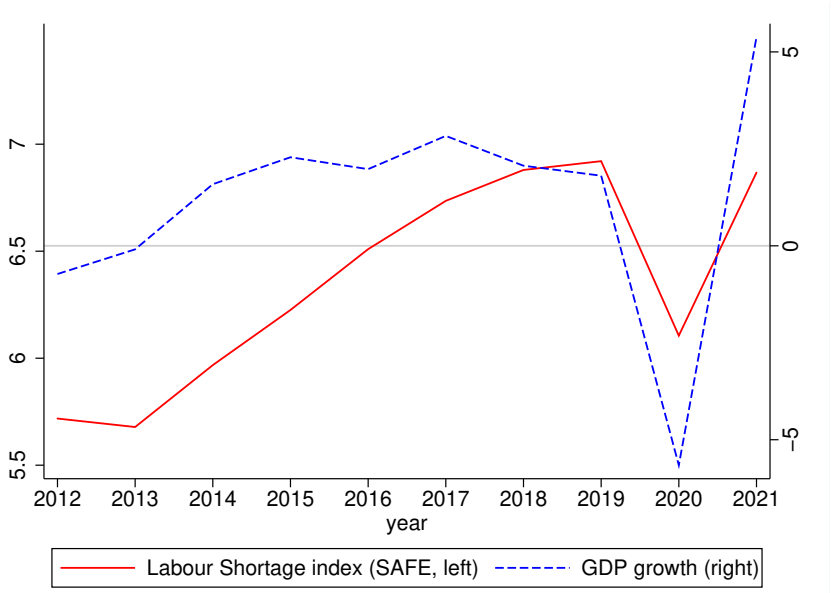
Utilising the regional and sectoral information of the Orbis data, we merge additional aggregate data from Eurostat. These include among others regional labour market variables, like the unemployment rate or the labour force participation rate, sectoral job requirements regarding skills and education, and country-level labour market policy indicators like the unemployment benefit replacement rate or labour market service expenditures. The regional variables included in our data set are collected at NUTS 2 level according to the Eurostat definition used since January 2021. This includes 283 regions of all EU member states (incl. the UK until 2020) over our sample.

2.4 Descriptive statistics

In this subsection we aim to present some stylised facts about labour shortages to get a better understanding of the heterogeneities in Europe. In order to do so, Figures 3 to Figure 7 depict labour shortages across time, regions and sectors. Figure 3 compares the weighted average of labour shortages in the EU with the EU GDP growth rate over time. In parallel with the economic expansion since 2012, the average labour shortage has increased. With the COVID-19 pandemic-related containment measures, labour demand dropped and accordingly perceived labour shortages declined. Yet, with the release of social distancing measures, GDP recovered quickly in the following year, and so also labour shortages became more prevalent again. Currently, we observe historically high levels of labour constraints even compared to the more distant past, using the factors limiting production index as indicator (see Figure A.3). This pattern is not only observed at European level, but also when we look at the development in individual countries. Figure 4 shows the average

labour shortage development for the largest five euro area countries and all have experienced a steady increase in the last decade with a short interruption in 2020. While the cyclical pattern is very similar, there are important structural differences across countries, shown by the significant differences in labour shortage levels. The average German firm faces a two-point higher level of labour shortage (on a ten-point scale) compared to the average Spanish firm. Although Spanish firms face historically high constraints too, it is still below the level of German firms at the beginning of our data series in 2012.

Figure 3: Labour Shortage over the Business Cycle



Notes: Comparison of the development of EU GDP growth (right axis) and the weighted average SAFE labour shortage indicator (left axis) for the EU.

Important structural differences can also be observed across sectors (see Figure 5). Using the four groups of economic activities defined in SAFE, we see that trade firms experience significantly less labour shortage than the other sectors. While industry firms had the highest chance of facing labour shortages in 2012, the construction sector is in the lead at the end of our sample period. Again, we observe a clear cyclical pattern across all sectors that led to the highest level of labour shortage in 2022.

To focus on the structural differences, Figure 6 depicts the labour shortage averages over all years for each NUTS 1 region. The left map shows the labour shortages for firms operating in

Figure 4: Labour Shortage across EA Countries

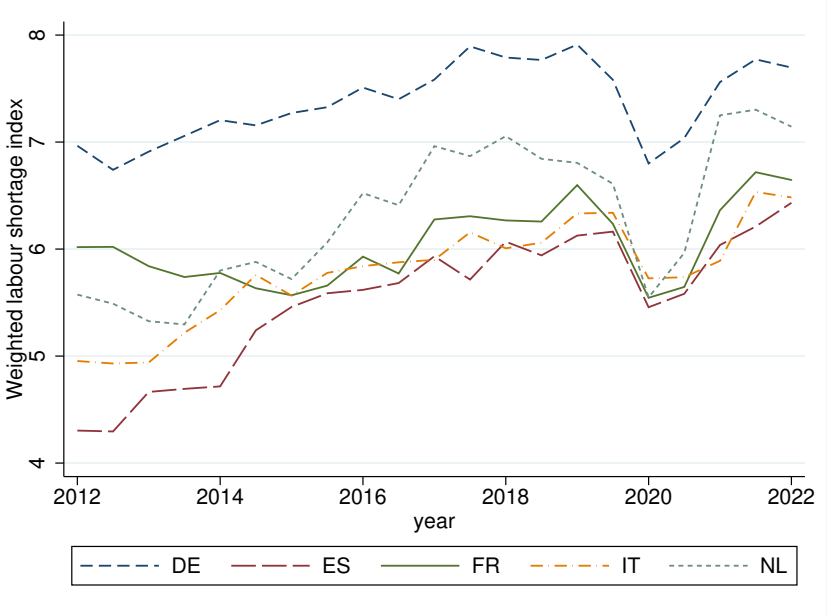
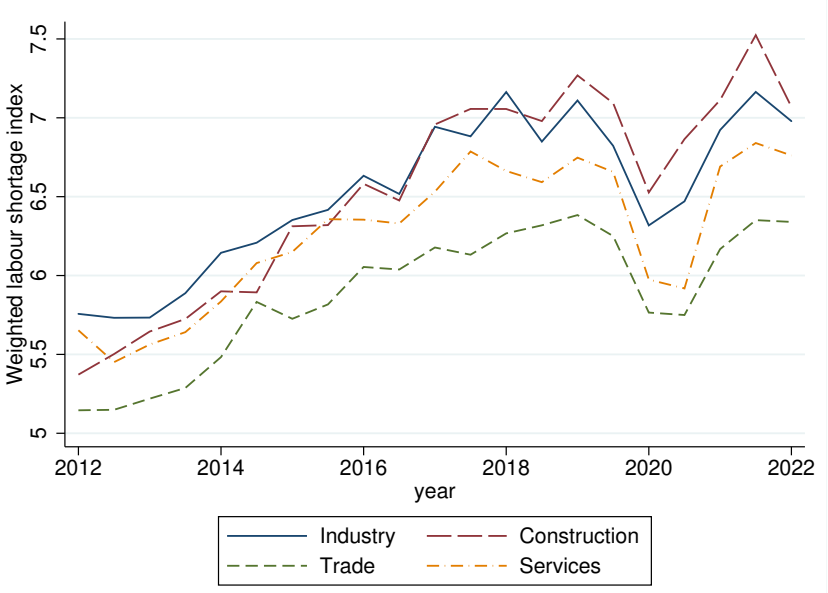


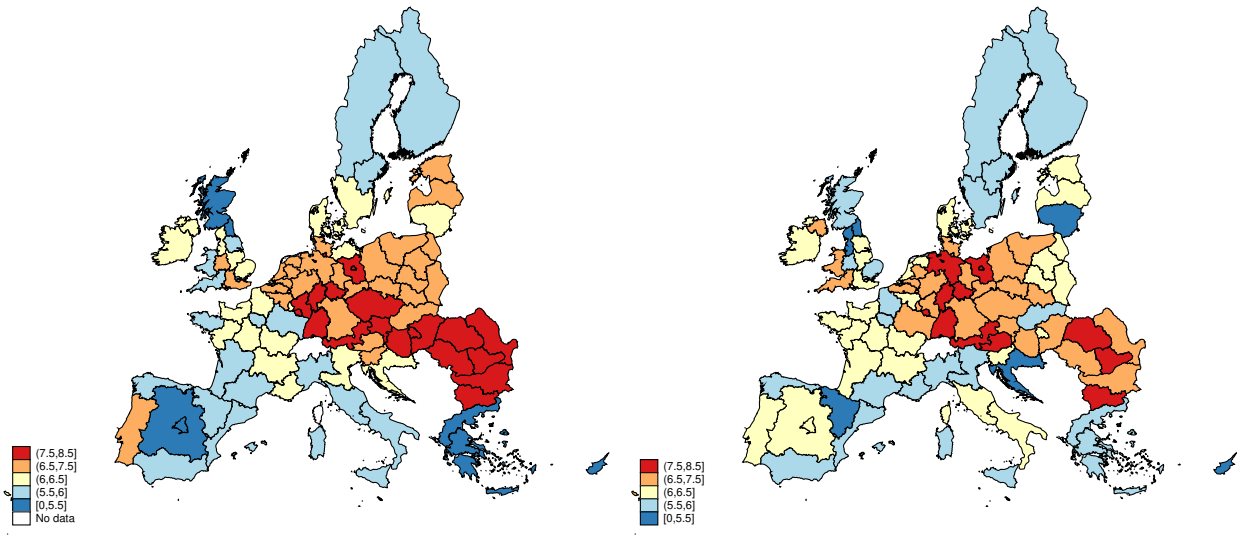
Figure 5: Labour Shortage across Main Sectors



the industry sector, the right map summarises the regional differences in the service sector, both depicting the average value in the respective region across the entire sample. High labour shortages (red) are predominantly experienced by firms in central and eastern Europe (Germany, Austria,

Czech Republic, Hungary, Romania and Bulgaria). In contrast, we find the lowest levels (dark blue) in the south and north of Europe (Greece, Italy, Sweden and Finland). While there are clear differences between the industry and service sector, we also observe a strong correlation in labour shortages between sectors. High shortages in the one sector also increases the likelihood in other sectors. Similarly, we see a high regional correlation within countries. National boundaries seem to imply differences in shortages due to structural, institutional and cultural differences.

Figure 6: Regional Labour Shortage Differences: Industry vs Service Sectors

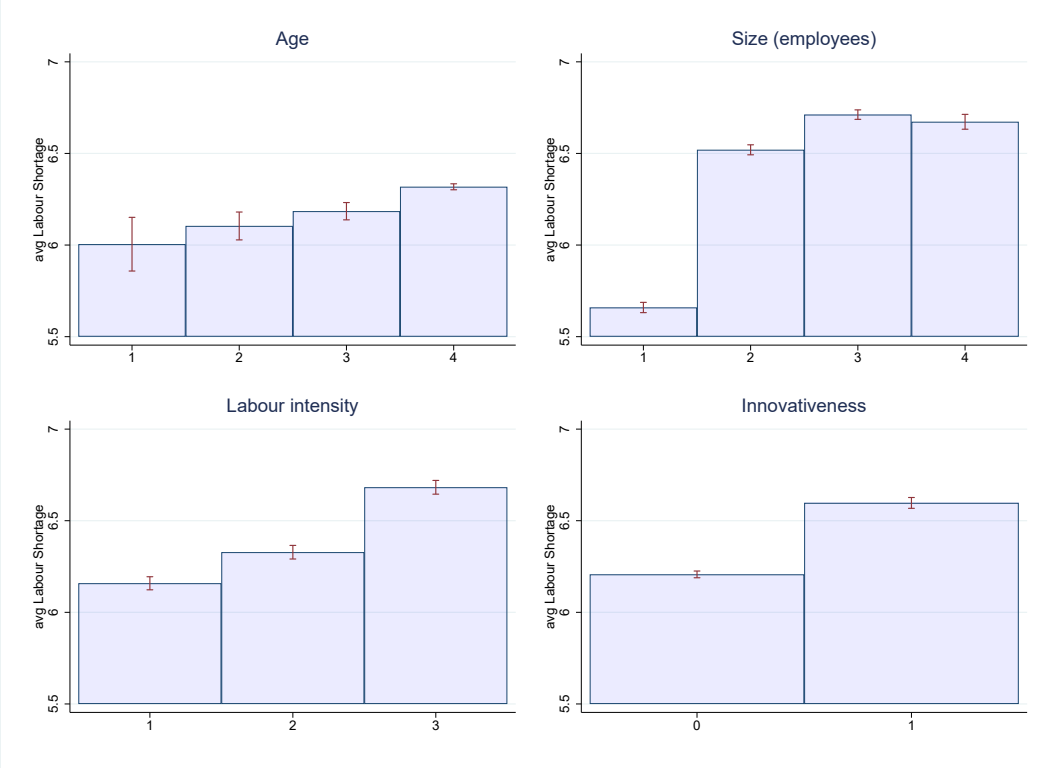


Notes: The map depicts the 98 NUTS1 regions of the EU (incl. UK) and the respective average labour shortages over all years in the industry and service sector. In the empirical analysis we go down to the NUTS 2 level.

Finally, Figure 7 depicts selected labour shortage differences between groups of firms to entertain the perspective that also firm characteristics matter to explain different perception in labour shortages. Older and larger firms seem to be stronger affected by labour shortages than young and small firms. Moreover, firms with a comparatively high share of workers in their production technology and innovative firms are more likely to face labour shortages. It is, however, important to note that these relationships are only bi-variate and do not control for other possible explanations. Hence, it is not clear what factors drive the relationships shown in the previous graphs and we need more elaborate empirical methods to disentangle the different factors, which we then apply in the following section.

Table 1 presents a numerical overview of the continuous variables used in the empirical analyses

Figure 7: Firm-specific Labour Shortages



Notes: Age categories: <2 years, 2-5 years, 5-10 years, >10 years; size categories: <10 employees, 10-49 employees, 50-249 employees, 250 or more employees; labour intensity = employees/capital - terciles; innovativeness: process innovation in the last year (no/yes).

of labour shortage. Besides the different aggregation levels (firm-specific, regional, sectoral), the variables can also be distinguished between slow-moving structural and fast-moving cyclical labour shortage factors. While sectoral GDP growth and the cyclical component of the regional unemployment rate are examples of cyclical variables, structural differences are described by the higher education share, the labour force participation rate or tax wedge.

Table 1: Summary Statistics

	Mean	SD	25th	Median	75th
Labour Shortage	6.36	2.83	5.00	7.00	9.00
Age	30.32	19.85	18.00	26.00	35.00
Size (employees)	125.24	907.47	7.00	28.00	91.00
Employment growth	0.11	17.44	-3.87	0.00	5.61
Size (assets in mn.)	2,918	$8.90e^5$	0.3	1,750	8,643
Return-on-assets	8.34	402.27	3.87	9.09	16.61
Average annual wage (in tsd. EUR)	32.86	22.61	13.98	29.73	47.23
Average real wage growth	0.76	16.18	-5.97	0.88	7.58
Problems/constraints	5.76	1.85	4.60	5.80	7.00
sectoral GDP growth	1.78	7.48	-0.06	2.31	4.68
Inflation rate	1.42	1.77	0.65	1.25	2.15
Unemployment rate, cycle	-0.06	0.68	-0.48	-0.08	0.31
Unemployment rate, trend	8.27	5.17	4.78	7.11	9.73
High education share	33.30	10.39	24.80	32.90	40.20
Part-time share	15.68	10.11	7.34	14.56	22.25
Labour force participation	73.68	5.28	70.56	73.82	77.54
Elderly share	22.25	3.48	20.24	22.37	24.37
Tax wedge	42.14	6.11	37.76	41.87	47.73
Unemployment benefit replacement rate	54.56	19.85	46.30	61.10	69.00
Labour market service expenditure/GDP	0.15	0.12	0.06	0.11	0.24
Job turnover rate	8.01	2.42	6.64	7.88	9.42
Required skills	1.82	0.65	1.33	1.64	2.20
Required high education	39.07	13.57	31.15	37.51	44.91

Notes: SD stands for standard deviation.

3 Who is facing labour shortages?

We argued in Section 1 that perceived labour shortages by firms cover both the quantitative and the qualitative element, the tightness and the matching efficiency component. To test this, we need to unpack the potential determinants of labour shortages. What kind of firms tend to face higher labour shortages? What is the role of regional labour supply, the lack of sufficient educational attainment, the importance of sectoral dimensions, such as skill requirements or the country-specific features? We do so by testing a broad range of explanatory variables at country, regional, sectoral and firm level in a panel regression framework and combine it with a relative importance analysis.

3.1 Empirical setup

We evaluate the statistical and economic relevance of labour shortage factors in a multi-level panel regression analysis. This means that we use variables at different aggregation levels (firm, sector, region and country) to describe our dependent variable in a fixed effects panel regression. These different layers improve the distinction of cyclical and structural factors in comparison to an analysis only based on country or firm characteristics. We consider these layers also when we control for unobserved heterogeneity by including country, sector and year fixed effects in the analysis. The regression equation looks as follows:

$$y_{i,r,c,s,t} = \alpha + \beta_1 BC_{i,r,s,t} + \beta_2 LS_{r,t} + \beta_3 Sec_{s,t} + \beta_4 Inst_{c,t} + \beta_5 X_{i,t} + \alpha_c + \alpha_s + \alpha_t + \epsilon_{i,r,c,s,t} \quad (1)$$

where $y_{i,s,r,c,t}$ is the labour shortage experienced by a firm i, in sector s, region r, country c and year t during the last six months, described on a scale from 1 to 10. α is the constant, while $\epsilon_{i,r,c,s,t}$ is the idiosyncratic error term. $BC_{i,r,s,t}$ captures variables that describe the business cycle at regional (cyclical unemployment rate), sectoral (GDP growth rate) or firm level (economic outlook). On top, the year fixed-effects α_t capture the common European business cycle.

The subsequent variables tend to capture the structural dimension of labour shortages at our different levels of aggregation. $LS_{r,t}$ contains variables that describe the labour supply at regional (NUTS2) level, like the labour force participation rate, the part-time employment share, the higher education share, the share of elderly people and the unemployment rate trend. $Sec_{s,t}$ summarises sectoral characteristics, like the job turnover rate and educational and skill requirements, while $Inst_{c,t}$ captures labour market institutions, including the labour market service expenditure per GDP, the income tax wedge and the unemployment benefit replacement rate at country level. $X_{i,t}$ captures a broad set of firm characteristics, including age, size categories (employees and assets), past turnover growth, sales expectations and indicator variables capturing firms' innovation activities. In addition, we add the average value of the other problems reported by a firm in the

SAFE to control for potential pessimism or systematic behaviour in choosing a value from 1 to 10.[3] The covariates are all included in the current period t. In this part, endogeneity concerns would arise if variables are determined simultaneously. Yet, variables like the size in terms of assets or employees, are described by categories, so that changes due to common shocks are less likely. Other variables do not seem to face a similar risk. In addition, we run robustness checks with lagged structural variables and do not find changes in the results as shown in Section 3.3.

α_c, α_s and α_t are the respective country, sector and year fixed effects. These are controlling for unobserved heterogeneity and hence reduce omitted variable bias of the coefficient estimates. In addition, they help to evaluate the importance of structural and cyclical variables even if they are not observable. As noted above, the year fixed effects can be interpreted as a common business cycle across the whole EU.[4] In contrast, the country and sector fixed effects capture all structural differences that tend to remain unchanged in the ten years under consideration, like different languages or long-lasting policies. This is also the reason why we do not control for firm fixed effects, as these would capture many country, sector and firm differences without the possibility of a distinction and an evaluation of the relative importance. One caveat remains necessary, though. We attempt to make a distinction between variables that move more slowly (structural) and those that move more at a cyclical frequency. Such an analysis is best done with higher frequency data. Given that firm data are only available at a low frequency, annual data are chosen, even though they are not ideal to separate cyclical and structural effects very clearly.

As mentioned before, the labour shortage indicator used in this paper is ordinal, based on a scale from 1 to 10. This usually calls for an estimation approach dealing with a limited dependent variable, like an ordered logit estimator. However, the literature lacks a consensus on how to implement a fixed effects estimator for an ordered logit model. While ignoring unobserved heterogeneity could bias the results, assuming cardinality instead of ordinality leads to similar results if the dependent

[3]Beside including a large number of variables in the regression, we exclude others although they were relevant in former analyses: the equity ratio or ownership categories are always insignificant; the female labour force participation rate and sales are multicolinear with the LFPR and firm size; migrant share and trade union density have many missing observations; wages and loans for HR measures are endogenous. Other variables like minimum wages, child care, training offered by firms or firm-specific demographics are simply not available.

[4]In addition to the common EU business cycle, year fixed effects also capture common trends. Given the annual sample of 15,000 firms in over 200 regions, common trends in demographics or digitization are however limited, and the close relationship between the cumulative EU GDP growth and the year dummy coefficients points towards a cyclical component.

variable is evaluated on a scale of 7 or 10 steps (Ferrer-i Carbonell and Frijters, 2004; Dickerson et al., 2014). Riedl and Geishecker (2014) show in a Monte Carlo simulation that linear fixed effects models estimate nearly the same relative coefficients than several proposed ordered fixed effects logit models. Thus, the interpretation of the effects' direction, their statistical significance and their relative importance is reliable in linear fixed effects models as we use in this section. Moreover, the results are robust to a re-coding of the labour shortage variable to a dummy variable and using a fixed effects logit model or the estimation of an ordered fixed effects logit model with a "Blow-Up and Cluster" estimator as suggested by Baetschmann et al. (2015). The results are shown in Section 3.3.

To assess the relative importance of the variables in explaining labour shortages, we supplement our regression framework with a dominance analysis. The aim of such extension is to partition explained variance among groups of predictors to understand their role in a regression equation (Tonidandel and LeBreton, 2011). Dominance analysis does not describe the additional variation explained (= marginal increase in R^2) by a new factor as criticised in the past, but examines the change in R^2 resulting from adding a predictor to all possible subset regression models. By taking the average across all possible models, one obtains a variable's general dominance weight, which considers its own contribution and those of others (Budescu, 1993).

3.2 Results

Table 2 captures the results of our baseline regression in a waterfall format. We start with the cyclical factors in column (1), then gradually add the structural dimensions starting with the regional and sectoral data in column (2) and then the firm characteristics in column (3). The last column, column (4), then contains the dominance analysis for the complete regression in column (3), indicating the importance of respective variable blocks of the model.

As expected, cyclical factors play a role in explaining labour shortages. The sectoral GDP growth is positive and significant, yet relatively small in terms of coefficient size. The cyclical part of the regional unemployment rate has a much more pronounced impact. A decrease in the unemployment rate by about 3 percentage points, for example, rises the shortage indicator by half

an index point. Also the firms' economic outlook matters, with a more positive economic outlook going hand in hand with a higher perceived shortage of labour.[5] In addition, the year fixed effects, the proxy for the common cycle, are most relevant. Table 5 shows that the labour shortage variable is higher by one full index point in boom years such as 2018, 2019 or 2021.

Moving to the more structural variables, the (trend component of the) unemployment rate has a negative relation to labour shortages. This is a finding well documented in the literature. Also other studies, like Holzer (1994) for the US, or Mok et al. (2012) for New Zealand, find that the lower the local unemployment rate, the lower the pool of available workers, hence firms declare higher labour shortages. A similar labour supply argument can be made for the labour force participation rate. The coefficient in Table 2 suggests that with a lower share of the working age population willing to work in a region, firms tend to express higher labour shortages. Also the share of the population with a tertiary education matters for firms. A higher share of well-educated worker ameliorates the shortages experienced by firms. The negative coefficient of the share of part-time employed (while controlling for the labour force participation) seems odd at first, implying that less part-time employment increases labour shortages. However, Levanon et al. (2014) suggest that firms appreciate part-time work as the intensive margin, the working hours, allows for some flexibility in times of excess demand. Yet, the interaction term with the labour force participation rate suggest that this argument has a limit. The lower the labour force participation rate in a region, the more biting does a higher share of part-time employment become for firms' labour demand.

In addition to the regional labour supply, Table 2 documents that sector- or work-specific skills impact labour shortage. The more specific the skill requirements, the more difficult it is to find suitable workers and the more likely it is that firms express that they face labour shortages (in line with the findings by Haskel and Martin (2001) for the UK and Holzer (1994) for the US). But also more generally, there are significant differences across sectors. The sector fixed effects, as depicted in Table 4, show that labour shortages, e.g., in the health, construction, information & communication, or manufacturing sector are by around half an index point higher than other sectors like the trade sector.

[5]The negative economic outlook is first positively significant in columns (1) and (2) of Table 2, which would be counter-intuitive. Yet, when adding all necessary firm-level control variables, in column (3), it turns insignificant, suggesting an omitted variable bias in the first two columns.

Besides the region and sector dimensions, there remain vast differences across countries. The country fixed effects absorb most of those differences. Table 3 suggests that institutional differences across countries have one of the largest explanatory powers. Labour shortages in Germany, Austria and Belgium are around 2 index points higher than in Spain (the baseline in the regression). If compared to Cyprus or Greece the difference extends by one further index point. We also include relevant institutional variables, such as the unemployment benefit (UB) replacement rate or the income tax wedge that impact the reservation wage and thus determine the incentive to work. Similarly, we include labour market (LM) expenditures by the general government that should describe the government's effort to undertake active labour market policies. Those variables have been documented well in the literature as affecting labour supply (e.g. Carrillo-Tudela et al., 2021). However, most of those variables are captured by our country fixed effects. As explained in Section 3.1, we include country fixed effects to account for unobserved heterogeneity. However, given that country-level institutional variables, as the ones described above, hardly move over time, they are captured by those country fixed effects. When we remove those country fixed effects they turn significant. This suggests that we can interpret the country fixed effects in the broad sense as capturing different country-specific institutional settings that, for example, impact the incentive and ability to seek work and therefore affect the pool of available workers.

The advantage of our empirical setup and of the unique data set is that we can add a firm-level dimension to explain labour shortages. The dominance analysis attributes nearly half of the variation in variance to this level. Younger and larger firms (both in terms of employees and assets) tend to have higher labour shortages. In particular, the incidence of larger firms being more affected is documented also in other studies (Watson et al., 2006; Holzer, 1994). Healy et al. (2015) suggests that those patterns could be explained by larger firms having more advanced production processes or higher absolute turnover. But similar to other studies, the significance of size may just be the result of scale, as the shortage variable in the SAFE survey does not allow to determine the incidence of skill shortages per employee in each firm.

Also faster growing firms (past and expected growth) and more innovative firms are in higher need of additional worker and manager to implement company's growth and development plans (in line with Watson et al. (2006) for the UK or Holzer (1994) for the US).

Firms that have the impression that they face problems across various dimensions when asked by the SAFE survey (difficulty to find customers, difficulty to access finance, increase in production costs, or concerns about competition and regulatory burdens) tend to also be more negative about the availability of employees. With this positive and significant coefficient, we control for the different interpretation across firms and also for other adverse factors affecting the firms.

Table 2: Labour shortage correlates

	(1) Cyclical factors	(2)=(1) + Structural factors	(3) = (2) + Firm characteristics	Dominance weights
Sectoral GDP growth	0.006***	0.006***	0.010***	8.58%
	(0.002)	(0.002)	(0.003)	
Economic outlook (ref: unchanged)	ref.	ref.	ref.	
positive	0.093***	0.237***	0.099***	
	(0.032)	(0.032)	(0.036)	
negative	0.067**	0.153***	0.029	
	(0.030)	(0.030)	(0.036)	
Regional unempl. rate (cycle)	-0.140***	-0.094***	-0.089***	
	(0.022)	(0.022)	(0.025)	
Regional unempl. rate (trend)		-0.035***	-0.027***	32.58%
		(0.006)	(0.006)	
Regional high educ share		-0.016***	-0.011***	
		(0.002)	(0.002)	
Regional labour force part.		-0.030***	-0.040***	
		(0.008)	(0.008)	
Regional part-time share		-0.124***	-0.157***	
		(0.034)	(0.038)	
Part-time share × LFPR		0.001***	0.002***	
		(0.000)	(0.001)	
Regional elderly share		-0.002	0.004	
		(0.006)	(0.006)	
Sectoral job turnover rate		-0.015	-0.000	
		(0.018)	(0.020)	
Sectoral required skills		-0.015	0.135**	
		(0.048)	(0.054)	
Sectoral required high educ		-0.002	-0.002	
		(0.003)	(0.003)	
Tax wedge		0.001	-0.032	
		(0.018)	(0.020)	
Unemployment benefit replacement rate		-0.002	-0.002	
		(0.003)	(0.004)	
Labour market expenditure		0.559	-0.970*	
		(0.513)	(0.570)	
Firm age			-0.003***	58.84%
			(0.001)	

Table 2: Labour shortage correlates

	(1) Cyclical factors	(2)=(1) + Structural factors	(3) = (2) + Firm characteristics	Dominance weights
Size employees (ref: 1-9 employees)			ref.	
10-49 employees			0.435***	
			(0.041)	
50-249 employees			0.589***	
			(0.051)	
250+ employees			0.661***	
			(0.064)	
Size assets (ref: 1st quintile)			ref.	
2nd asset quint			0.151***	
			(0.049)	
3rd asset quint			0.156***	
			(0.053)	
4th asset quint			0.055	
			(0.060)	
5th asset quint			-0.120*	
			(0.067)	
Turnover growth (ref: unchanged)			ref.	
turnover growth >20%			0.271***	
			(0.047)	
turnover growth 1%-20%			0.219***	
			(0.036)	
turnover decline			-0.279***	
			(0.049)	
Process innovation			0.146***	
			(0.034)	
Management innovation			0.145***	
			(0.031)	
Product innovation			0.052	
			(0.032)	
Sales innovation			-0.070**	
			(0.035)	
Problems/constraints			0.575***	
			(0.008)	
Sales outlook (ref: unchanged)			ref.	
positive			0.040	
			(0.033)	
negative			-0.315***	
			(0.040)	
constant	5.875***	8.662***	6.081***	
	(0.119)	(1.027)	(1.171)	
Year FE	yes	yes	yes	yes
Country and sector FE	no	yes	yes	yes
Observations	89516	83757	54762	54762
Adjusted R^2	0.024	0.116	0.275	0.275

Notes: Robust standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Overall, it is inherently difficult to clearly distinguish variables into cyclical and structural

Table 3: Country differences

	(1) Country FE Baseline Spain	
DE	2.05***	(0.28)
BE	1.85***	(0.32)
AT	1.78***	(0.22)
EE	1.52***	(0.18)
CZ	1.18***	(0.25)
NL	0.98***	(0.31)
HU	0.98***	(0.26)
SK	0.81***	(0.25)
FR	0.81***	(0.20)
LU	0.76***	(0.23)
BG	0.73***	(0.23)
SE	0.72***	(0.18)
MT	0.64**	(0.32)
DK	0.63***	(0.23)
LV	0.61***	(0.16)
SI	0.55***	(0.17)
FI	0.53***	(0.14)
PL	0.26	(0.18)
RO	0.23	(0.21)
PT	0.11	(0.12)
ES	0.00	(.)
HR	-0.01	(0.18)
IE	-0.09	(0.22)
IT	-0.13	(0.20)
LT	-0.36**	(0.17)
EL	-0.73***	(0.16)
CY	-1.25**	(0.58)
Observations	54762	

Notes: Robust standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 4: Sector differences

	(1) Sector FE Baseline Trade	
Human health	0.72***	(0.17)
Construction	0.67***	(0.05)
Other services	0.47**	(0.20)
Accommodation and restaurants	0.45***	(0.08)
Information and communication	0.31***	(0.09)
Manufacturing	0.28***	(0.04)
Transportation	0.27***	(0.07)
Professional and scientific activity	0.26***	(0.07)
Agriculture and forestry	0.23	(0.24)
Education	0.19	(0.36)
Finance and insurance	0.12	(0.19)
Water supply and waste	0.05	(0.10)
Administrative services	0.04	(0.09)
Trade	0.00	(.)
Mining and quarrying	-0.11	(0.23)
Arts and entertainment	-0.25	(0.16)
Energy supply	-0.32**	(0.13)
Observations	54762	

Notes: Robust standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 5: Year differences

	(1) Year FE Baseline 2013	
2013	0.00	(.)
2014	0.12	(0.08)
2015	0.27***	(0.08)
2016	0.53***	(0.08)
2017	0.72***	(0.09)
2018	0.97***	(0.09)
2019	1.00***	(0.09)
2020	0.44***	(0.09)
2021	1.01***	(0.12)
Observations	54762	

Notes: Robust standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

groups. Yet, assigning variables to one or the other group, the dominance analysis described in Section 3.1 allows us to broadly distinguish between the role of the fast-moving cyclical and slow-moving structural factors. Over the full sample, the cyclical variations only explain some 9% of the variance, if we focus on the most confined cyclical variables in Table 2, i.e., the sectoral GDP growth, the cyclical part of the unemployment rate, the growth outlook of the firm and the (common cycle) year fixed effects. However, this seems to be the lower bound estimate. In particular, many of the variables captured in the structural bloc are known to also move with the cycle, in particular the labour force participation rate (Cajner et al., 2021). Moreover, as pointed out by Elsby et al. (2015), the distinction between business cycle shifts and structural shifts only holds under some assumptions, so one could argue that (mis-)match has a cyclical element, probably captured in some of the variables we apply, such as job turnover. Also the firm's turnover variables have both a structural and cyclical component. We apply some sensitivity analysis in this respect, showing that the cyclical developments could increase to 12.1% if we assume that other variables (i.e. the labour force participation rate, the firm sales expectation, and job turnover rate) so far attributed to the structural pillar are predominantly cyclical as well. See Table A.4 for a comparison of specifications. This notwithstanding, over the entire sample, labour shortages seem to be significantly affected by structural variables, while in some years, in particular when the economy runs hot, the cycle plays a key role as well. Variations at the firm level explain somewhat more than at the sector, region or country level, which is of course also inherently driven by the firm level focus of the analysis.

3.3 Robustness

With the results of the baseline regression in mind, we want to show the robustness of our estimation in various regards.

In Section 3.1, the choice of the linear fixed effects model was outlined in greater detail and we argued that relative coefficients should be similar to the choice of the ordered fixed effects logit model, which is usually meant to cover limited dependent variables. This notwithstanding, we recode data to fit a fixed effects logit model and estimate an ordered fixed effects logit model with a 'Blow-Up and Cluster' estimator as suggested by Baetschmann et al. (2015). Table A.2 in the Appendix covers those regressions. The results of the baseline regression in Section 3.2 remain highly

robust under the alternative choice of estimation. Nearly all coefficients in column 1 (Logit) and 2 (Blow-up-and-cluster) in this table remain qualitatively unchanged, i.e., keeping the same overall size, the same sign and significance level. In some cases, variables even increase their explanatory power or become significant while they were not in the baseline regression (e.g. job turnover rate or tax wedge).

The SAFE question on labour shortages asks the firm about their non-availability of 'skilled' staff and managers. So, how is our dependent variable interpreted? There is plenty of evidence in the literature that firms understand this question rather broadly, far beyond technical skills. When employers refer to skill shortages this actually captures a range of behavioural attributes or social skills along motivational or attitudinal dimensions, including, but not limited to reliability, ability to work without supervision (Healy et al., 2015; Green et al., 1998; Bosworth et al., 1992). Moreover, it is hard to distinguish between shortages in skilled and unskilled labour within a few seconds in an interview. We also document this by showing that the development of labour shortages are surprisingly similar in high-tech, knowledge intensive and other (low-skilled) firms as depicted in Figure A.4.

Another important question is whether explanatory variables should enter the regression with a lag to ensure exogeneity. The October wave of the SAFE asks for labour shortages in the last six months. We claim that the balance sheet data for this whole year, like the annual sectoral and regional data, are well-equipped to enter the equation contemporaneously, as in our baseline model in Table 2. We also do so, in order not to loose unnecessarily many observations given that we have a rotating panel (as described in Section 2). This notwithstanding, we show in Table A.3 that also when entering the regional and sectoral variables with a lag, the results remain highly robust.

As the fixed effects included in equation 1 control for unobserved heterogeneity and additionally explain structural and cyclical differences, they are an important part of our analysis. While removing fixed effects might increase the statistical significance of labour market institutions and cyclical variables, it also reverses several effects implying a crucial bias. Including firm fixed effects would drop several (constant) firm characteristics and does not allow to distinguish between country, sectoral or firm-specific effects as many of them are captured by firm fixed effects. Hence, they would hinder the identification of different drivers of labour shortages.

In addition, we apply the following robustness checks with different fixed effects specifications: By adding country-year and sector-year fixed effects that capture all variables only varying along these dimensions, but not firm-specific characteristics, the baseline results are not altered a lot as shown in column 3 of Table A.2. Moreover, replacing country fixed effects with regional (NUTS2) fixed effects changes the results only marginally compared to the baseline specification. In the same vein, the estimated coefficients are very similar when we use regional labour supply variables at a higher aggregation level (NUTS1 or country level). Exceptions are the elderly share which gets significant at NUTS1 level and the higher education share which is not statistically significant anymore at country-level. To keep the paper short, those results are not reported in the annex, but are available from the authors.

While the overall sample of the SAFE is constructed to be representative along firm sizes, sectors and countries, this is not necessarily the case after loosing 15% of the observations due to the matching with Orbis data or even more due to non-reporting. Thus, we run a sample selection model (Heckman, 1979) to evaluate the relevance of missing observations. By using variables like size category, age category, country and economic activity that are available for all SAFE observations, we find significant effects in the selection equation. The coefficients in the regression equation are, however, nearly identical with the results in Table 2 as the "Heckman" correlation (between the errors in the selection and regression equation) is low and not statistically significant. This holds for the sample with all matched SAFE-Orbis observations as well as for the sample used for the labour shortage analysis (column (3) of Table 2) as shown in column 4 of Table A.2. This result is also in line with the descriptive statistics for the different samples which show very similar values.

Eventually, we analyse whether our conclusions change for specific sub-samples. In particular, we compare the results for the whole EU with those for euro area and non-euro area countries. While some coefficients of aggregate variables become insignificant due to the smaller variation, the coefficients are similar and the conclusions remain the same as for the overall sample. Results are also robust when we compare firms in high-tech sectors, knowledge intensive sectors and other sectors. Also those results are for brevity reasons not reported in the annex, but are available from the authors upon request.

4 Impact of labour shortages

In this Section, we move on to the second part of our analysis, the impact of labour shortages on firms' hiring decisions and wage growth. Search and matching models suggest that tighter labour markets lead to higher wages due to higher bargaining power of workers (Mortensen and Pissarides, 1994). In this vein, the empirical literature on the wage Philips curve finds a positive relationship between economic tightness and wage growth (Gali, 2011). Using our information on labour shortages at firm-level, we want to add to the literature by analysing the role of labour shortages for the development of wages and employment. We will do this at the firm level to describe the behavioural response of firms to shortages as well as at the regional level to capture potential spill-overs across firms.

4.1 Empirical setup

In analysing the effects of labour shortages on wages or employment, endogeneity concerns are more apparent than in the descriptive analysis about different explanatory factors. There are two sources that make causal interpretations difficult: omitted variables and reversed causality. Therefore, we explain in the following paragraphs how we use an instrumental variable (IV) panel regression framework to tackle these problems. The regression equation estimated at firm-level looks as follows:

$$y_{i,s,c,t} = \alpha + \beta_1 \widehat{LabourShort}_{i,t} + \beta_2 X_{i,t} + \beta_3 (\widehat{LabourShort}_{i,t} * D_{i,t}) + \alpha_c + \alpha_s + \alpha_t + \epsilon_{i,s,c,t} \quad (2)$$

where $y_{i,s,c,t}$ is either the real wage growth or the employment growth of firm i, in sector s, country c and year t. α represents the intercept, while $\epsilon_{i,s,c,t}$ is the idiosyncratic error term. The coefficient of $LabourShort_{i,t}$ β_1 is of main interest, as it describes the expected change in the dependent variable if our labour shortage indicator increases by one, holding all control variables ($X_{i,t}$) fixed. Since we expect different effects of labour shortages on wages and employment depending on the demand firms face and for different types of firms, we also include interaction effects in later exercises, where $D_{i,t}$ represents different sub-sets in terms of type of firm (i.e. labour intensity, fast growing firms). α_c, α_s and α_t are the country, sector and year fixed effects, respectively. The standard errors are robust and corrected for country clusters.

To describe wage development, we use the change in the firm's wage bill per employee. We correct these nominal wages with the sectoral GDP deflator. In typical Phillips curve specifications, it is common to control for inflation expectations. However, several papers (e.g. Nickel et al., 2020) have found that the backward looking or current time component of inflation is relatively more important for wage formation. Also aside of the Phillips curve framework, using the past year's or current inflation to proxy inflation expectations has become a common approach (e.g. Coibion and Gorodnichenko, 2015; Ball and Mazumder, 2011). As such, by deflating the wage growth with the sectoral GDP deflator, we follow this approach. While this is our baseline approach, alternative specifications keep those results qualitatively unchanged. Such alternatives include using nominal wage growth and adding the current or lagged inflation to the controls. They also encompasses versions in which inflation rates measured by the Harmonized Index of Consumer Prices (HICP) instead of the sectoral GDP deflator are used to better account for workers' perspective of real wage developments.

As omitted variable bias stems from common determinants of the dependent variable and labour shortage, demand or productivity shocks are potential causes, but also the firm size or the sector can play a role. Hence, we control for a broad set of firm characteristics like firm size, sales expectations (both in categories), firm age, lagged wages and lagged employment. In the wage regressions, we also control for labour productivity growth (in line with recent augmented Phillips curve equations, see Nickel et al. (2020)). Moreover, we include country, sector and year fixed effects to control for various sources of unobserved heterogeneity.[6] We include all variables in categories or lagged. While the inclusion of a broad set of controls and fixed effects limits the omitted variable bias, the possibility of reversed causality keeps endogeneity concerns present. Hence, we make use of an exogenous and relevant variable to control for the endogeneity of $LabourShort_{i,t}$ in the first stage.

In line with many recent empirical papers (e.g. Granja and Moreira, 2023; Le Barbanchon et al., 2023), we construct a shift-share instrument, also known as Bartik-style instrument (Bartik, 1991), at firm-level. This instrument can be applied to both the wage growth and employment growth equations. The main idea is to create a variable that fulfills the exogeneity and relevance condition

[6] We do not include firm fixed effects as we would lose all firms with only one observation (36%) and firms without variation in their labour shortage response (additional 10%) only indirectly help estimating β_1. This would increase standard errors and type 2 errors (false negative results) unnecessarily, as described by deHaan (2021).

for a reliable IV application by multiplying a shift and a share-component both related to labour shortages. The *shift* component describes the variation in labour shortages over time at an aggregate level. Thereby, the overall development is still present, but the influence of the individual observation to the aggregate is very small or even nullified when the aggregate change is calculated separately for each case without the own observation (leave-one-out approach). The *shift* component reduces reversed causality as the aggregate variable usually has influence on the firm-specific wage and employment development but it is less likely that firm-specific wage and employment growth affect aggregate labour shortages systematically (Broxterman and Larson, 2020). The *share* component captures the pre-determined structural exposure of a sector. It is argued to be exogenous, since it builds on past information and describes long-lasting relationships. Given the persistency and the pre-determinedness of this component, the *share* component is the main source of exogeneity. As shown by Goldsmith-Pinkham et al. (2020), it is sufficient that the *share* is exogenous for the shift-share instrument to be valid.

In our instrument, the *shift* component ($\overline{LabourShort_{-i,c,s,t}}$) is the average labour shortage in each country-sector. To enhance exogeneity, we calculate firm-specific country-sector averages leaving the respective firm out of the calculation. The *share* component ($\overline{LabourShortID_{r,s,t-j}}$) represents the share of firms in each region-sector that suffered from labour shortage in the past (including all available former observations). A firm is assumed to suffer from labour shortage, when it experiences an above median shortage, which implies responses with 8, 9 or 10 to the labour availability question in the SAFE (= $LabourShortID$). Thereby, we capture the structural pre-determined exposure to labour shortages faced by firms. The exclusion restriction requires that the instrument affects the outcome only through its impact on labour shortages. This is plausible in the case of our shift-share instrument given that the instrument explicitly focuses on a subpart of the shortage variation. The firm-level instrument is formed by multiplying the shift and the share component:

$$ShiftShare_{f,t} = \overline{LabourShort_{-i,c,s,t}} * \overline{LabourShortID_{r,s,t-j}} \tag{3}$$

As described by Breuer (2022), shift-share instruments can have various forms, but they all

aim to be exogenous and relevant for the particular endogenous variable of interest. Besides the arguments for exogeneity based on the construction of the shift and the share component, it is possible to test the exogeneity by overidentification tests, if other relevant instruments are available. For that, we construct two other shift-share instruments at firm-level. They consist of the country-sector labour shortage average leaving the own observation out (as before) and either the lagged labour shortage or the share of firms suffering from labour shortage in the last period for each region-sector. Thereby, we also use pre-determined information, but they are less persistent and the number of observations is smaller compared to our main instrument. The overidentification tests, based on the wage growth and employment growth equations, support our assumption of the shift-share instruments' exogeneity. Additionally, Goldsmith-Pinkham et al. (2020) suggest the application of alternative estimators to evaluate the validity and exogeneity of the instruments. Using the Limited Information Maximum Likelihood (LIML) estimator instead of Two-Stage Least Squares (2SLS) estimator leads to the same results.

Regarding the relevance of our instrument, we evaluate the first stage regression estimates, calculate the heteroscedasticity robust F-Statistic as suggested by Kleibergen and Paap (2006) and conduct the respective weak instrument test. All support the conclusion that our shift-share instrument is a strong instrument for the labour shortage indicator used in the wage and employment regressions. In the first stage regression, the estimated coefficients of our instrument are statistically significant and positive (see Table A.5), and we can reject the null hypothesis of weak instruments. The F-Statistic, testing for the exclusion of our instrument, is always above 10 as recommended by Stock et al. (2002).

4.2 Results

In this Section we present the main results on the impact of labour shortages on wage and employment growth. Table 6 starts with the insights on the wage side. As described in the previous Section, the regression equation 3 can be thought of as firm-level extended version of the Phillips curve. We control for standard slack (the regional unemployment rate), productivity growth (growth in real turnover per number of employees) and various other firm-level control variables. As already noted, inflation expectations are controlled for by deflating the firm's wage growth with the sectoral GDP

deflator.

In line with the large literature on Phillips curves for European data, we find a negative and strongly significant coefficient for the unemployment rate that suggests that lower unemployment in a region tends to increase wage pressures (see Nickel et al. (2020) for an overview of results). Moreover, productivity growth at firm level has a positive sign and is strongly significant (in line with Duval et al., 2022). Higher productivity implies that the total gain from any employer-employee match is higher and firms can hire more workers or pay higher wages (Adrjan and Lydon, 2019).

We add to the standard Phillip's curve specification our measure of labour shortages, which is instrumented by the shift-share instrument described in the previous Section. The relevance of our instrument is depicted by the F-statistics at the bottom of Table 6, which are always above 10. As discussed earlier, we add this variable to see whether there is additional explanatory power coming from the shortage indicator as an additional dimension of slack (here expressed as the unemployment rate) in the labour market. The variable has a positive and significant impact on wage growth, implying that firms pay a wage growth premium the more labour shortages they perceive to attract new employees and keep the current staff. This result is in line with Morissette (2022), Le Barbanchon et al. (2023) or Healy et al. (2015). Those studies confined to individual countries find that with higher labour shortages, i.e., fewer people available to work, bargaining power shifts to employees and result in higher wage growth.

The positive impact of labour shortages on wage growth is a general finding for our entire sample, suggesting that this wage growth premium is to some extent structural. Yet, the effect is particularly strong in case of firms growing strongly at times of high demand. In Table 6 in column (2) we depict the interaction between strongly growing firms and labour shortages. Such firms top up their wage growth in addition to less growing firms.

We also control for different labour intensities across firms. In column (3) we include a dummy indicating firms that operate with a high labour-to-capital ratio. The variable is negative, significant, and sizable in terms of magnitude. Generally, labour-intensive firms pay on average around 5% lower wage growth compared to other firms. The interaction term with our labour shortage variable suggests that there is a countervailing effect at play. The more those labour-intensive producing firms face labour shortages, the more they are willing to make up the distance to other firms by

paying considerably higher wages.

To put the coefficients of labour shortages into perspective, it is helpful to compare it to the development of wages and shortages in our sample. The average within-firm standard deviation of labour shortages is 1.81, which implies that a change of one or two points at our ten-point labour shortage scale is a common phenomenon. The increase of labour shortage by one point leads to an increase in wage growth by 1.4 pp (ceteris paribus) in our main specification in column (1). Given the average wage increase of 0.76%, this corresponds to two years of wage growth. It is also important to note that we describe the effects for all employees in a firm. Since wages of existing employees are usually less often and less strongly adjusted compared to job movers, the coefficient in this regression table underestimates the wage growth premium paid to newly hired employees in case of prevalent labour shortages.

In Table 7, we move from the impact on wages to the impact on hiring. The coefficient of the regional unemployment rate is again significant. The positive sign can be interpreted as a greater pool of available resources to feed firms' hiring needs. Our main variable of interest, labour shortages, is not significant in column (1) alone, neither promoting nor hindering employment growth over the entire business cycle. This is plausible as some firms are successfully addressing their labour shortages through hiring. As we are here only capturing the quantity and not the quality or the degree of matching, it could well be that some firms address a shortage by hiring, although less suitable employees. The insignificant coefficient, however, probably also captures a share of firms that intend to hire, but that do not find a match due to the lack of staff and therefore choose not to hire. Zooming into strongly growing firms versus other firms, we find in column (2) that those firms increase their workforce in the reaction to excess demand. Yet, quickly growing firms, that at the same time face labour shortages, hire less than comparable firms without (or with less) labour shortages, as suggested by the significant and negative coefficient of the interaction terms in Table 7. This state-contingent impact of labour shortages on employment growth has also been shown by Bellmann and Hübler (2014) for German firms.

A similar picture emerges for firms that rely over-proportionally on the factor labour in their production, as shown in column (3). In unconstrained circumstances, such firms hire more than other firms that grow less. Yet, in the face of labour shortages their employment growth declines

Table 6: 2SLS regression results - wage growth

	real wage growth		
	(1)	(2)	(3)
Regional unempl rate (t-1)	-0.147**	-0.149**	-0.155**
	[0.039]	[0.048]	[0.052]
Labour shortage	1.419*	1.419*	1.387*
	[0.797]	[0.808]	[0.780]
Excess demand (firm)		-4.902	
		[3.349]	
Excess demand (firm) × LS		0.837*	
		[0.487]	
Labour intensity 3rd tercile			-5.454***
			[1.627]
Labour intensity 3rd tercile × LS			0.502**
			[0.221]
log average wages (t-1)	-6.044***	-6.028***	-6.579***
	[0.690]	[0.604]	[0.657]
log employment (t-1)	0.517***	0.500***	0.592***
	[0.136]	[0.121]	[0.123]
Productivity growth	0.297***	0.296***	0.296***
	[0.032]	[0.032]	[0.032]
Firm controls	yes	yes	yes
Country, sector, year FE	yes	yes	yes
Observations	34269	33798	33664
Adjusted R^2	0.229	0.217	0.219
F-Statistic	48.752	24.917	17.245

Notes: Country clustered standard errors in brackets, firm controls include age, size categories, competitiveness, profitability and sales expectations - not shown for brevity, detailed results are available upon request.
* p<0.10, ** p<0.05, *** p<0.01.

significantly compared to non-labour-intensive producing firms.

The adverse impact of labour shortages on hiring by firms is also documented in Le Barbanchon et al. (2023). The finding that employment growth is even negative for firms with high labour shortages could also be reasoned by firms substituting labour for capital. The higher and more structural the labour shortages, the more firms might be willing to invest in capital to reduce manual work.

In addition to the firm-level regressions, we aggregate data to conduct regional Philips curve

Table 7: 2SLS regression results - employment growth

	employment growth		
	(1)	(2)	(3)
Regional unempl rate (t-1)	0.064*	0.066**	0.073**
	[0.033]	[0.027]	[0.035]
Labour shortage	-0.382	-0.215	0.033
	[0.594]	[0.541]	[0.539]
Excess demand (firm)		12.663***	
		[3.044]	
Excess demand (firm) × LS		-1.213**	
		[0.424]	
Labour intensity 3rd tercile			15.061***
			[1.845]
Labour intensity 3rd tercile × LS			-1.554***
			[0.278]
log average wages (t-1)	3.004***	3.198***	4.062***
	[0.607]	[0.594]	[0.661]
log employment (t-1)	-1.807***	-1.802***	-1.917***
	[0.325]	[0.339]	[0.341]
Firm controls	yes	yes	yes
Country, sector, year FE	yes	yes	yes
Observations	39045	38504	38217
Adjusted R^2	0.041	0.047	0.033
F-Statistic	47.751	25.000	17.560

Notes: Country clustered standard errors in brackets, firm controls include age, size categories, competitiveness, profitability and sales expectations - not shown for brevity, detailed results are available upon request.
* p<0.10, ** p<0.05, *** p<0.01.

and employment regressions in the spirit of Duval et al. (2022). We estimate the following equation:

$$y_{r,t} = \alpha + \beta_1 \widehat{LabourShort}_{r,t} + \beta_2 LS_{r,t} + \alpha_r + \alpha_t + \epsilon_{r,t} \tag{4}$$

Equation 5 is similar to equation 3 but without the firm-specific control variables. We slightly reformulate the labour shortage instrument to be suitable at regional level. It matches the traditional Bartik instrument more closely, as Bartik (1991) conducted his analysis also at regional level. We keep the aggregate and firm-level instruments as similar as possible to make them comparable. At the regional level, the *shift* component is the annual change in the average labour shortage for

each country-sector cluster. The *share* component is the region-sector share of firms that suffered from labour shortage in the past. The regional instrument is then the sum over all sector-specific shift-share products. Formally, this looks as follows:

$$ShiftShare_{r,t} = \sum_{s} \Delta\overline{LabourShort_{c,s,t}} * \overline{LabourShortID_{r,s,t-j}} \tag{5}$$

Moreover, we include a range of labour supply variables at the regional level regression. $LS_{r,t}$ contains the labour force participation rate, the part-time share, the higher education share, the share of older citizens. In addition, we control for productivity growth, economic slack (here the unemployment rate) and the level of wages and employment. The equation also contains regional and time fixed effects.

Table 8 contains the results of the aggregate regressions. Compared to the firm-level estimations, the most interesting change is that of the coefficient of the labour shortage variable. The coefficient is more than two times as large as in the firm-level regression. This is plausible as the regional aggregate represents labour shortages in entire regions. Hence, firms need to pay a significantly higher wage premium if the shortage is wide-spread.

Table 8: Aggregate 2SLS regression results

	(1) real wage gr	(2) empl gr
Regional labour shortage	3.638*	0.396
	[2.148]	[1.617]
Regional log average wages (t-1)	-3.398*	1.488
	[1.850]	[1.308]
Regional log employment (t-1)	-0.402	-0.358
	[0.335]	[0.299]
Regional unemployment rate (t-1)	0.094	0.277*
	[0.202]	[0.157]
Regional average productivity growth	0.0980*	
	[0.0566]	
Regional controls	yes	yes
Regional and year FE	yes	yes
N	1776	1850
adj. R^2	0.094	0.062
F-Statistic	28.70	27.53

Regional clustered standard errors in brackets; regional controls include the labour force participation rate, the part-time share, the higher education share and the share of older citizens; productivity, wages, employment and labour shortages are regional averages
* p<0.10, ** p<0.05, *** p<0.001

4.3 Robustness

As in the Section on labour shortage factors, we aim for robust results in our impact analysis. Hence, we have conducted several consistency checks regarding the instrument, the model specifications and our sample of firms.

First, we check the reliability of our instrument by estimating the reduced form regression, i.e., including the shift-share instrument in the second stage equation instead of the labour shortage indicator. Table A.6 shows that the results are significantly positive in terms of wage growth and Table A.7 depicts insignificantly negative effects for employment growth, as in the IV specifications in Tables 6 and 7. An adjustment of the share component using only observations going back three years or more to strengthen the exogeneity argument produces robust results. Using the lagged labour shortage or lagged regional unemployment rate as an instrument as in Kölling (2022), we find F-statistics below 10 and partly contrasting results. Hence, we did not follow this approach.

Including the lagged labour shortage as an additional control variable does not alter our results, because these information are already included in our shift-share instrument.

Next, we test for non-linear effects, as we expect that wages and employment might react differently if the labour shortage indicator changes from one to two or from nine to ten. Therefore, we estimate equation 3 with our labour shortage dummy ($= 1\ if\ LabourShort > 7$). The effects are larger than for a small change, but in line with main results. Table A.6 and A.7 show the large significant positive effects on wage growth and non-significant negative effects on employment growth. An alternative definition of our labour shortage dummy ($= 1\ if\ LabourShort > 5$) leads to similar results. Restricting the sample to firms with high labour shortages leads to insignificant effects, probably due to the smaller sample and less variation in the treatment variable. The extension of the regression by a squared labour shortage term requires a second exogenous and relevant instrument that captures other information than the first one. Using another shift-share instrument with lagged labour shortage as share component in addition to our main instrument, results, however, in insignificant squared coefficients (due to the similarity of the instruments). In a nutshell, there are at best tentative signs of non-linear effects that we can document on the basis of our data set.

As we expect firms to react to labour shortages primarily temporarily and to prevent non-stationary variables on the left-hand-side of our regression, we opted for growth rates in our baseline regression. The results are, however, very similar by using the log real wage and the log employment as dependent variable. Table A.6 shows a significantly positive effect of labour shortages on the wage level with a magnitude of 1.7%, similar to the wage growth specification. The negative effect of labour shortages on employment in Table A.7 is larger and gets statistically significant, in line with our results for labour-intensive firms and the findings of Le Barbanchon et al. (2023).

While the year fixed effects control for unobserved heterogeneity between years like a common cycle across firms, they are hard to interpret and partially capture other trends like aging societies. Hence, we replace it with the EU real GDP growth rate that captures a common cycle more directly. Table A.6 and A.7 present that higher GDP growth leads to higher wage and employment growth as expected and the effects of labour shortages are consistent with our year FE specification. The effect of higher labour shortages on wage growth is significantly positive and the effect on employment

growth is slightly negative. In order to control for different dynamics across countries and sectors, we replace the country, sector and year FE with country-year and sector-year FE. This modification captures even more unobserved heterogeneity, but does not change our conclusions, as shown in Table A.6 and A.7. The effect of labour shortages on wage growth increases somewhat and the effect on employment growth remains insignificantly negative.

Finally, we also test to which extent the sample influences our findings. Kalemli-Ozcan et al. (2019) note that the Orbis data for some countries[7] cover a shorter horizon and are less reliable. Therefore, we also run the impact regressions without firms from these countries. As these countries are relatively small, except Poland, and firms from these countries often have missing information regarding their number of employees, the results do not change a lot. Hence, the sample of countries under consideration does not affect our results.

5 Conclusions

Labour shortages have become increasingly prevalent in advanced economies, including Europe. Yet, little is known so far about which firms tend to face more shortages and the impact of such shortages on labour market outcomes.

In this paper we contribute to closing this gap. We create a large pan-European firm-level data set of labour shortages, including firm, regional and sectoral characteristics, spanning across 28 EU countries, 283 regions and 18 sectors. To our knowledge this is the most comprehensive data set analysing labour shortages covering micro-level data so far. Linking labour shortages to labour market tightness and matching efficiency, we relate our study to key concepts in labour market analysis such as the standard search and matching models (Mortensen and Pissarides, 1994) and the Phillips curve that help to explain hiring outcomes and wage determination.

We contribute to the literature in two ways. First, we shed light on the factors that explain labour shortage differences. Over the full sample, we find that labour shortages are significantly driven by structural factors. Firms identify higher labour shortages if the region exhibits a lack of labour supply. This is true for quantities, such as lower labour force participation rates or higher

[7] Bulgaria, Croatia, Cyprus, Czech Republic, Greece, Ireland, Latvia, Luxembourg, Lithuania, Malta, Poland, Portugal, Romania, Slovakia and Slovenia

unemployment rates, but also applies to the quality of labour. In regions with below-average share of highly educated people, more firms tend to have labour shortages. Similarly, the higher the skill requirements in a sector, the more firms tend to identify labour shortages. Also country differences play a pivotal role in explaining labour shortages across firms. Lastly, firm differences explain labour shortages. Younger, faster-growing and more innovative firms face the largest labour shortages.

Notwithstanding the importance of structural factors, labour shortages (not surprisingly as a measure of tightness) move with the business cycle. More buoyant sectoral or regional activity and a lower cyclical unemployment rate tend to push up labour shortages.

In a second step, we document the impact that labour shortages have on hiring decisions of firms and wage growth. We find that labour shortages have a significant impact of wages and employment (at least under some circumstance). In line with search and matching models, we find that labour shortages, an expression of tightness but also possibly less efficient matching, have a bearing on employment and wage growth. Applying a Phillips curve-like specification at firm-level, we find that firms with higher labour shortages across time pay a wage growth premium to keep incumbent and attract new workers. Wage growth is topped up further when the firm is strongly growing or produces in a particularly labour-intensive way. When running the analysis on aggregated data at regional level, our results are robust.

Employment growth is on average not significantly impacted by labour shortages. This seems to reflect two countervailing forces. On the one hand, part of the labour shortages are successfully addressed by the firm through new hires. On the other hand, some parts of the intended hiring cannot be satisfied (matching inefficiency, insufficient labour supply). This becomes clearer when looking at fast growing firms. While they are able to increase employment, labour shortages hold them back in satisfying overall hiring intentions. The higher the perceived shortages, the more it turns the firm-specific hiring towards zero.

The important structural dimension of labour shortages that we find in our paper has an implication for national structural policies. Designing policies that increase the quality of labour (e.g. upskilling) and the quantity of labour (e.g. tapping inactive workers and attracting inward migration) has the potential to reduce labour shortages going forward. In the absence of such policies, and in the face of an anyway ageing population, labour shortages have the potential to increase

further, possibly with a rising share of firms paying a wage premium. This, in turn, if broad enough, could have an implication for aggregate wage growth in the economy, to be monitored then also by other policies, including monetary policy.

In terms of future research, our data set opens the possibility to study a range of related questions, including how labour shortages potentially affect other dimensions of firm activity, such as their innovation capacities or productivity.

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A Appendix

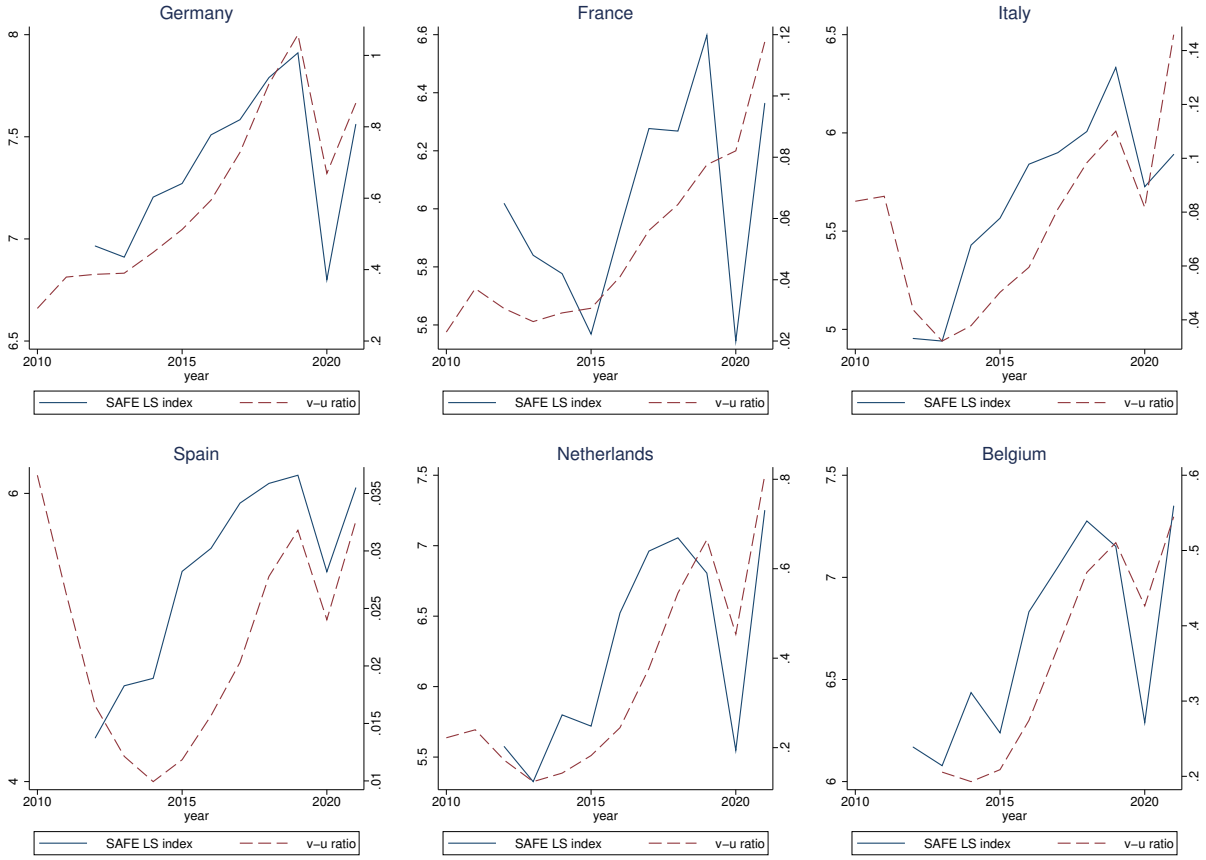
Table A.1: Variable description

Variable	Description	Source
Labour shortage	"How much has the non-availability of skilled staff or experienced managers burdened your enterprise in the past six months?" Scale 1-10, 1 = not at all, 10 = extremely.	SAFE
Labour shortage ID	Indicator variable equals 1 if labour shortage is larger than 7, 0 otherwise	SAFE
Age	Years since incorporation	Orbis
Employment	Number of people employed by a firm at the end of the year	Orbis
Labour size category	1 (<10 employees), 2 (10-49 employees), 3 (50-249 employees), 4 (>250 employees)	SAFE
Total asset	Total value of assets according to firm's balance sheet at the end of the year, negative values removed	Orbis
Asset size category	Quintiles of total asset distribution, 1 lowest quintile, 5 highest quintile	Orbis
Labour intensity	Number of employees per real valued capital	Orbis, calc
Labour productivity	Real turnover per number of employees, in log and annual growth rates	Orbis, calc
Turnover growth	Over the last three years, how much did your firm grow on average per year? >20% (1), 1%-20% (2), no growth (3), got smaller (4)	SAFE
Excess demand (firm)	Identifier whether turnover growth is >20% (1) or not (0)	SAFE, calc
Profit	How has your firm's profit developed over the last six months? Increased (1), remained unchanged (2), decreased (3)	SAFE
ROA	Return-on-Assets = EBITDA divided by total assets	Orbis
Average wage / Costs per employee	Total annual costs of employees per number of employees, in log and annual growth rates	Orbis
Economic outlook	How has your general economic outlook changed over the last six months (insofar as it affects the availability of external financing)? Improved (1), remained unchanged (2), deteriorated (3)	SAFE
Business outlook	How has your firm specific outlook regarding sales and profit changed over the last six months (insofar as it affects the availability of external financing)? Improved (1), remained unchanged (2), deteriorated (3)	SAFE
Process innovation	Have you introduced a re-organisation of different parts of the enterprise to increase efficiency or reduce costs in the past 12 months? Yes (1), No (2)	SAFE
Management innovation	Have you introduced a new organisation of management in the past 12 months? Yes (1), No (2)	SAFE
Product innovation	Have you introduced a new or significantly improved product or service to the market in the past 12 months? Yes (1), No (2)	SAFE
Sales innovation	Have you introduced a new way to sell your goods or services in the past 12 months? Yes (1), No (2)	SAFE
Firm problems	Average firm problems or constraints: finding customers, competition, access to finance, production costs, regulation (evaluated on a scale from 1 to 10)	SAFE, calc
Competition	"How much has competitive situation burdened your enterprise in the past six months?" Scale 1-10, 1 = not at all, 10 = extremely	SAFE
GDP growth (sector)	real annual GDP growth per 1-digit NACE sector	Eurostat
Unemployment rate	Regional unemployment rate at NUTS 2 level	Eurostat
Unemployment rate (cycle)	Cyclical component of HP filtered unemployment rate at NUTS 2 level, series for calculation starting in 1999	Eurostat, calc

Table A.1: Variable description

Variable	**Description**	**Source**
Unemployment rate (trend)	Trend component of HP filtered unemployment rate at NUTS 2 level, series for calculation starting in 1999	Eurostat, calc
Job turnover	New hires per employeed workers, per (1-digit ISCO) occupation, weighted to 1-digit NACE sectors	Eurostat
High education share	Tertiary education share at NUTS 2 level	Eurostat
Required education (sector)	Share of vacancies requiring higher education in 2014, per (1-digit ISCO) occupation, weighted to 1-digit NACE sectors	CEDEFOP
Required skills (sector)	Average number of required specific skills per job (according to OVAT) in each 1-digit NACE sector in 2018	CEDEFOP
Part-time share	Share of employees working part-time at NUTS 2 level	Eurostat
LFPR	Labour force participation rate: Share of employed and unemployed people in the working age population (age 15-64) at NUTS 2 level	Eurostat
Elderly share	People older than 64 years as a share of overall population (over 15 years)	Eurostat
UB replacement rate	Net replacement rate of unemployment benefits, single earner couple with 2 children, median income, 7 months of unemployment	Eurostat
Tax wedge	Income tax wedge single person median income	Eurostat
LM service expenditure	Labour market service expenditure in percent of GDP	Eurostat

Figure A.1: Labour shortage vs labour tightness



Notes: This graph compares the development of average labour shortages with the vacancy-to-unemployment ratio in six EU countries. The left axis corresponds to the LS index, the right axis to the v-u-ratio Source: Eurostat and SAFE.

Table A.2: Labour shortage correlates - Robustness

	Logit	Blow-up-and-cluster	FE structure	Sample selection 2nd stage
Sectoral GDP growth	0.006***	0.013***	0.006*	0.007***
	(0.002)	(0.002)	(0.003)	(0.002)
Economic outlook (ref: unchanged)	ref.	ref.	ref.	ref.
positive	0.089**	0.078**	0.082**	0.076***
	(0.038)	(0.038)	(0.036)	(0.028)
negative	0.157***	-0.040	0.046	0.007
	(0.037)	(0.038)	(0.036)	(0.027)
Regional unempl. rate (cycle)	-0.061**	-0.113***	-0.023	-0.055***
	(0.025)	(0.024)	(0.035)	(0.019)
Regional unempl. rate (trend)	-0.014**	-0.167***	-0.018**	-0.026***
	(0.007)	(0.014)	(0.007)	(0.005)

Regional high educ share	-0.012***	0.008	-0.010***	-0.012***
	(0.002)	(0.009)	(0.002)	(0.002)
Regional labour force part.	-0.029***	0.037*	-0.039***	-0.014*
	(0.009)	(0.021)	(0.009)	(0.007)
Regional part-time share	-0.174***	-0.370***	-0.171***	-0.072**
	(0.040)	(0.109)	(0.041)	(0.030)
Part-time share × labour force part.	0.002***	0.004***	0.002***	0.001*
	(0.001)	(0.001)	(0.001)	(0.000)
Regional elderly share	0.008	-0.026	0.003	0.001
	(0.007)	(0.022)	(0.007)	(0.005)
Sectoral job turnover rate	0.002	0.181***	-0.008	0.015
	(0.018)	(0.021)	(0.026)	(0.014)
Sectoral required skills	0.153***		0.116**	0.113***
	(0.052)		(0.053)	(0.042)
Sectoral required high educ	-0.001		-0.002	0.001
	(0.003)		(0.003)	(0.002)
Tax wedge	0.001	0.071***		0.001
	(0.019)	(0.020)		(0.015)
Replacement rate UB	-0.005	-0.004		-0.007***
	(0.003)	(0.004)		(0.003)
LM service expenditure	-0.002	-0.573		-0.636
	(0.586)	(0.606)		(0.429)
Firm age	-0.003***		-0.003***	-0.004***
	(0.001)		(0.001)	(0.001)
Size employees (ref: 1-9 employees)	ref.	ref.	ref.	ref.
10-49 employees	0.221***	0.162*	0.426***	0.356***
	(0.036)	(0.086)	(0.041)	(0.045)
50-249 employees	0.291***	0.227*	0.571***	0.486***
	(0.046)	(0.118)	(0.050)	(0.060)
250+ employees	0.290***	0.319*	0.632***	0.439***
	(0.061)	(0.156)	(0.063)	(0.102)
Size assets (ref: 1st quintile)	ref.	ref.	ref.	ref.
2nd asset quint	0.116***	0.077	0.148***	0.118***
	(0.042)	(0.110)	(0.049)	(0.036)
3rd asset quint	0.095**	0.211	0.164***	0.085**
	(0.047)	(0.143)	(0.053)	(0.039)
4th asset quint	0.007	0.240	0.075	-0.032
	(0.055)	(0.169)	(0.058)	(0.044)
5th asset quint	-0.181***	0.446**	-0.101	-0.158***
	(0.065)	(0.198)	(0.066)	(0.050)
Turnover growth (ref: unchanged)	ref.	ref.	ref.	ref.
turnover growth >20%	0.182***	0.077	0.259***	0.318***
	(0.046)	(0.055)	(0.047)	(0.036)
turnover growth 1%-20%	0.125***	0.078*	0.211***	0.244***
	(0.037)	(0.040)	(0.035)	(0.028)
turnover decline	-0.153***	-0.075	-0.263***	-0.264***
	(0.049)	(0.052)	(0.049)	(0.037)
Process innovation	0.131***	0.100***	0.158***	0.157***
	(0.036)	(0.037)	(0.033)	(0.026)
Management innovation	0.155***	0.177***	0.145***	0.188***
	(0.033)	(0.036)	(0.031)	(0.024)
Product innovation	0.097***	0.027	0.048	0.026
	(0.034)	(0.037)	(0.032)	(0.025)
Sales innovation	-0.010	0.013	-0.066*	-0.113***

	(0.035)	(0.039)	(0.034)	(0.027)
Problem identifier	1.398***	1.293***		
	(0.045)	(0.054)		
Problems/constraints			0.573***	0.592***
			(0.008)	(0.006)
Sales outlook (ref: unchanged)	ref.	ref.	ref.	ref.
positive	0.033	0.086**	0.045	0.093***
	(0.034)	(0.035)	(0.032)	(0.025)
negative	-0.150***	-0.079*	-0.318***	-0.232***
	(0.042)	(0.041)	(0.040)	(0.030)
Constant	0.879		5.950***	3.335***
	(1.164)		(0.762)	(0.912)
Year FE	yes	no	yes	yes
Country and sector FE	yes	no	yes	yes
Firm FE	no	yes	no	no
Observations	56989	113059	54761	167224
Adjusted R^2			28.3	
Pseudo R^2	0.128	0.86		

Robust standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A.3: Labour shortage - lagged variables

	Lagged Structural factors
Sectoral GDP growth	0.010***
	(0.002)
Economic outlook (ref: unchanged)	ref.
positive	0.102***
	(0.036)
negative	0.030
	(0.036)
Regional unempl. rate (cycle)	-0.082***
	(0.025)
Regional unempl. rate (trend, t-1)	-0.021***
	(0.006)
Regional high educ share (t-1)	-0.011***
	(0.002)
Regional labour force part. (t-1)	-0.035***
	(0.009)
Regional part-time share (t-1)	-0.134***
	(0.038)
Part-time share (t-1) × participation rate (t-1)	0.002***
	(0.001)
Regional elderly share (t-1)	0.013*
	(0.007)
Sectoral job turnover rate (t-1)	0.068***
	(0.019)
Sectoral required skills	0.146***
	(0.053)
Sectoral required high educ	0.004
	(0.003)
Tax wedge (t-1)	-0.012

Table A.3: Labour shortage - lagged variables

	Lagged Structural factors
	(0.017)
UB replacement rate (t-1)	-0.001
	(0.003)
LM expenditure (t-1)	-1.733***
	(0.576)
Firm age	-0.003***
	(0.001)
Size employees (ref: 1-9 employees)	ref.
10-49 employees	0.445***
	(0.041)
50-249 employees	0.602***
	(0.051)
250+ employees	0.669***
	(0.064)
Size assets (ref: 1st quintile)	ref.
2nd asset quint	0.140***
	(0.049)
3rd asset quint	0.153***
	(0.053)
4th asset quint	0.051
	(0.060)
5th asset quint	-0.124*
	(0.067)
Turnover growth (ref: unchanged)	ref.
turnover growth >20%	0.278***
	(0.047)
turnover growth 1%-20%	0.222***
	(0.036)
turnover decline	-0.269***
	(0.049)
Process innovation	0.151***
	(0.034)
Management innovation	0.144***
	(0.031)
Product innovation	0.051
	(0.032)
Sales innovation	-0.070**
	(0.035)
Problems/constraints	0.578***
	(0.008)
Sales outlook (ref: unchanged)	ref.
positive	0.042
	(0.033)
negative	-0.317***
	(0.040)
Constant	3.827***
	(1.038)
Year FE	yes
Country and sector FE	yes
Observations	54831

Table A.3: Labour shortage - lagged variables

	Lagged Structural factors
Adjusted R^2	0.276

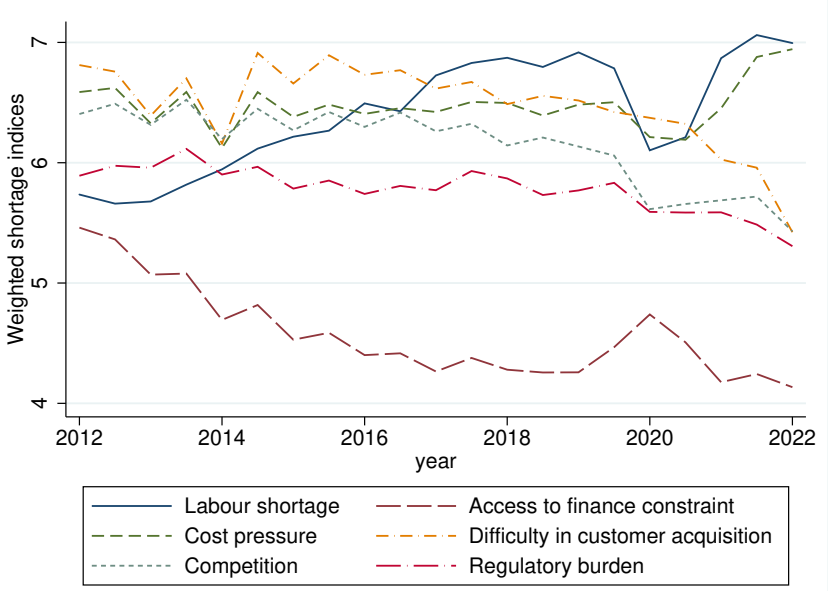
Notes: Robust standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A.4: Dominance analysis

	Cyclical factors	Structural factors	Firm characteristics
Baseline	8.58%	32.58%	58.84%
Lagged controls	8.74%	32.36%	58.94%
Extended cyclical factors	12.09%	30,01%	57.90%
Logit model	13.64%	52.70%	33.66%

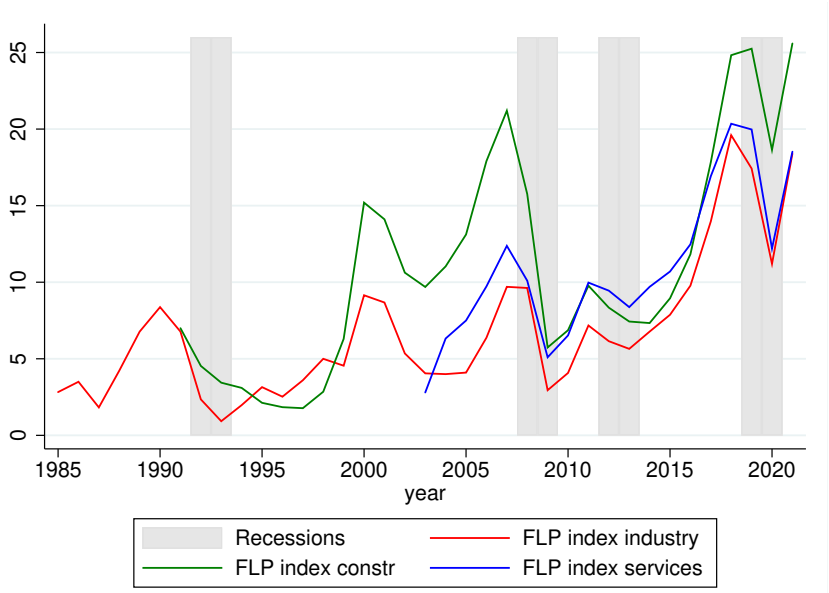
Notes: Baseline corresponds to the variable split in column (3) of Table 2.
The lagged controls specification relates to Table A.3.
In row 3 (extended cyclical factors) we shift the labour force participation rate, the firm sales expectation and the job turnover rate to the cyclical factors.

Figure A.2: Firm constraints



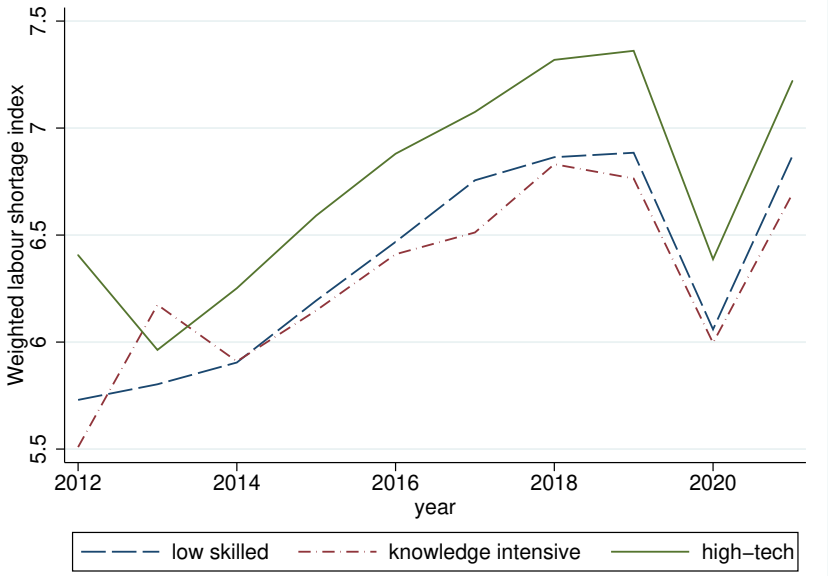
Notes: This graph shows the average development of constraints and problems faced by firms in the EU between 2012 and 2022. Source: SAFE.

Figure A.3: Historic labour shortages



Notes: This graph shows the development of labour shortages in the EU in the industry, construction and service sector since 1985. Source: Business & Consumer Survey.

Figure A.4: Skill intensive sectors



Notes: This graph shows the average development of labour shortages between 2012 and 2021 for high-tech, knowledge intensive and other firms according to Eurostat definition.

Table A.5: First stage regressions

	(1) labour shortage	(2) labour shortage	(3) labour shortage
Shift-share 1	0.145***		
	[0.018]		
Shift-share 2		0.110***	
		[0.017]	
Shift-share 3			0.052***
			[0.004]
Constant	6.602***	6.504***	5.045***
	[0.661]	[0.804]	[0.932]
2nd stage controls	yes	yes	yes
Country, sector, year FE	yes	yes	yes
N	41084	34339	13540
adj. R^2	0.179	0.181	0.287

Notes: Standard errors in brackets, country clustered
Shift-share 1 = $\overline{LabourShort_{-i,c,s,t}}$*$LabourShortID_{r,s,t-j}$
Shift-share 2 = $\overline{LabourShort_{-i,c,s,t}}$*$LabourShortID_{r,s,t-1}$
Shift-share 3 = $\overline{LabourShort_{-i,c,s,t}}$*$LabourShort_{i,t-1}$
* p<0.10, ** p<0.05, *** p<0.01.

Table A.6: Impact regression results - wage growth

	(1) OLS	(2) reduced	(3) dummy	(4) EU growth	(5) log wage	(6) granular FE
Labour shortage	-0.063**			0.804*	0.017**	1.511*
	[0.030]			[0.444]	[0.009]	[0.801]
Shift-share instrument		0.207*				
		[0.111]				
Labour shortage dummy (=1 if >7)			7.066*			
			[4.124]			
Regional unempl rate (t-1)	-0.152***	-0.152***	-0.148***	-0.094**	-0.002**	-0.153**
	[0.034]	[0.036]	[0.041]	[0.047]	[0.001]	[0.044]
Log average wage (t-1)	-6.271***	-6.267***	-6.103***	-6.105***	0.854***	-6.040***
	[0.674]	[0.678]	[0.627]	[0.644]	[0.017]	[0.633]
Log employment (t-1)	0.568***	0.562***	0.530***	0.509***	0.015***	0.581***
	[0.173]	[0.168]	[0.124]	[0.139]	[0.003]	[0.123]
Productivity growth	0.299***	0.299***	0.296***	0.298***		0.291***
	[0.031]	[0.031]	[0.032]	[0.032]		[0.033]
Log Productivity (t-1)					0.018***	
					[0.005]	
real GDP growth				0.439***		
				[0.118]		
Firm controls	yes	yes	yes	yes	yes	yes
Country and sector FE	yes	yes	yes	yes	yes	no
Year FE	yes	yes	yes	no	yes	no
C#Y and S#Y FE	no	no	no	no	no	yes
Observations	34269	34269	34269	34269	35273	34257
Adjusted R^2	0.285	0.286	0.236	0.264	0.945	0.180
F-Statistic			63.946	30.049	66.589	46.925

Country clustered standard errors in brackets
*p<0.10, **p<0.05, ***p<0.001

Table A.7: Impact regression results - employment growth

	(1) OLS	(2) reduced	(3) dummy	(4) EU growth	(5) log wage	(6) granular FE
Labour shortage	0.253***			-0.099	-0.020**	-0.264
	[0.043]			[0.421]	[0.009]	[0.627]
Shift-share instrument		-0.058				
		[0.088]				
Labour shortage dummy (=1 if > 7)			-2.005			
			[3.109]			
Regional unempl rate (t-1)	0.066**	0.065**	0.064**	0.036	0.001	0.053*
	[0.030]	[0.031]	[0.032]	[0.048]	[0.001]	[0.027]
Log average wage (t-1)	3.114***	3.070***	3.019***	3.025***	0.043***	3.166***
	[0.642]	[0.642]	[0.615]	[0.642]	[0.006]	[0.582]
Log employment (t-1)	-1.837***	-1.824***	-1.810***	-1.793***	0.963***	-1.851***
	[0.355]	[0.348]	[0.327]	[0.340]	[0.006]	[0.340]
real GDP growth				0.282***		
				[0.079]		
Firm controls	yes	yes	yes	yes	yes	yes
Country and sector FE	yes	yes	yes	yes	yes	no
Year FE	yes	yes	yes	no	yes	no
C#Y and S#Y FE	no	no	no	no	no	yes
Observations	39045	39045	39045	39045	39608	39035
Adjusted R^2	0.050	0.049	0.042	0.046	0.982	0.030
F-Statistic			75.010	28.974	53.157	50.709

Country clustered standard errors in brackets
*p<0.10, **p<0.05, ***p<0.001

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