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The impact of skills shortage on economic development in Germany: A mixed method approach

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Abstract:

In Europe, there is an increasing shortage of skilled workers and jobs remain vacant for long periods of time. The shortage of skilled workers has become a key issue for various stakeholders, as it not only makes it difficult to recruit and retain employees, but it is also seen as a significant barrier to innovation for companies. So far, most analyses of skills shortage take place at company level. We supplement this with a regional perspective, because many measures, especially those of policy makers, are conducted on the regional level. We examine the impact of skills shortage on various aspects of regional economic development. Using the spatial vector autoregressive panel model, significant effects on gross domestic product (GDP), employment are found, but not on research and development (R&D) activities. Expert interviews are used to dig deeper into the reasons for these findings, showing that the disadvantages of skills shortages on innovativeness are perceived, but relate to the future or to the more general economic situation.

Keywords: skills shortage, regional development, regional innovativeness, mixed method, VAR-approach

JEL Classifications: O10, O30, J23, J21, J11

1 Introduction

Hardly a day goes by without reading about the 'skills shortage' in the media (e.g. Specht 2022). Data from Germany shows that the shortage of skilled workers has worsened in recent years (Rudnicka 2024). Demographic developments, technological (structural) change and an overall increase in total employment are leading to bottlenecks in the labor market (Bellmann and Hübler 2014; Haskel and Martin 2001; Brunello and Wruuck 2021; Allaart et al. 2002).

Some scientific studies show negative effects on company development: Skills shortages can, for example, act as a barrier to innovation (Rammer et al. 2020; Horbach and Rammer 2022), lead to productivity losses (Morris et al. 2020; Bennett and McGuinness 2009; Backman 2014), or reduce the effectiveness of research and development (R&D) investments (Ministry of Finance Finland 2023). An adequate supply of skilled labor is crucial for an innovative and competitive economy (Burstedde et al. 2020). The argument is that without a sufficiently skilled workforce, companies have difficulties to develop and implement innovative ideas, which in turn affects their long-term competitiveness (Ministry of Finance Finland 2023).

Previous studies have often been conducted at company level (König and Brenner 2022; Horbach and Rammer 2022; Bellmann and Hübler 2014; Statista Research Department 2024b). Companies are important players in a region shaping the success and economic development of a region (Davidsson et al. 1994; Neffke et al. 2018). Based on the analyses on the firm level, it can be assumed that skills shortage slows down regional economic development and hinders regional innovation (Specht 2022). This applies in particular to less attractive regions, such as certain types of lagging regions or more rural regions (Hertrich and Brenner 2023). However, not every company and not every industry is affected by the skills shortage to the same extent (Burstedde et al. 2020; Morris et al. 2020). Among other things, the location of companies influences their possibilities to hire skilled workers. Nevertheless, the effects of skills shortage on the economic development and other circumstances in a region have not yet been empirically investigated. Analyses of the effects of skills shortage on regional or national economic development remain vague statements such as "in three to four years [they could] result in a phase of permanently shrinking gross domestic product" (Müller 2022:1). The regional level is also of specific policy interest because most governmental measures on skills shortage are conducted at regional level.

An analysis at regional level also sheds light on the question of whether the shortage of skilled workers is a problem that needs to be addressed at national level. Existing differences in skills shortages between regions might be compensated for through migration. If this works perfectly, the skills shortage is a supra-regional problem. If, on the other hand, regions with a greater shortage of skilled workers also have more significant negative effects on economic development, the problem of skills shortage must be tackled on a region-specific basis. This question is at the heart of the paper's analysis. A better understanding of the mechanisms and effects at regional level is important for regional decision-makers and the scientific discourse.

In this paper, we contribute to a better understanding of the effects of skills shortage on regions by a mixed method approach. First, we identify the effects of skills shortage on the economic development of regions using a spatial vector auto-regressive model (VAR-approach). We examine the effects of skills shortages on various economic variables, such as gross domestic product, employment and R&D activity at the regional level. With the help of 69 expert interviews with intermediaries and companies, we also analyze the specific explanations as to whether and why the shortage of skilled workers is detrimental to innovation and economic performance in the region. The combination of two approaches leads to a more detailed understanding of the regional impacts of skills shortage.

The following work is structured as follows: Section 2 deals with the theory of the skills shortage. Section 3 presents the two methodologies used. Section 4 is dedicated to the results of the statistical approach. Section 5 describes the various explanations given by the experts in the qualitative interviews. The paper ends with a conclusion (Section 6).

2 Theory

The theoretical section contains basic considerations on the definition of terms and mechanisms (Section 2.1). Section 2.2 deals with the effects of skills shortage on companies. Section 2.3 transfers the findings from section 2.2 to regions.

2.1 Skills shortage

In the English literature, terms such as labor shortage, skills shortage, skilled labor shortage, skill gap and skill mismatch can be found (Bott et al. 2011; Shah and Burke 2005). In addition to the general confusion of terms, there is no uniform definition of the term skills shortage in either academic or public discourse (Bellmann and Hübler 2014). "In labor market research, the term skills shortage is used when there are too few suitably qualified workers in relation to labor demand (job offers) or too few workers who can be qualified to meet the requirements" (Federal Employment Agency 2020:5). We also base our analysis on this definition. One measure to adequately (and easily) measure the bottleneck in the labor market is the use of vacancy times (Borghans et al. 1998). The vacancy period is calculated as the difference between the departure date and the earliest possible filling date of the position. If the filling date set in the job advertisement has not been exceeded, the vacancy period for jobs is zero days ("not vacant"). The longer the vacancy period, the more difficult it is to fill the job (Federal Employment Agency 2024, 2020). The labor market is divided into four segments in terms of job requirements: Helpers (unskilled jobs), skilled workers (jobs with qualified training), specialists (jobs with master craftsman or technician training or a university degree) and experts (jobs with a higher academic degree) (Federal Employment Agency 2019). Our analysis is based on the vacancy periods for the latter three categories.

2.2 The impact of the skills shortage on companies

Previous studies on skills shortages often examine companies (König and Brenner 2022; Horbach and Rammer 2022; Bellmann and Hübler 2014). Analyses show that skills shortage can have a negative impact on company development (Brunello and Wruuck 2021). According to Rammer et al. (2020), every second company with a shortage of skilled workers had to forego certain innovation activities. For 42% of the companies, the shortage of skilled workers led to delays or extensions in innovation projects and for 6% to project terminations. The shortage of skilled workers is perceived as a significant barrier to innovation by companies, and innovative companies are more likely to be affected by skills shortage due to discontinuing innovation projects (Horbach and Rammer 2022). In this sense, the shortage of skilled workers can reduce the effectiveness of Research and Development (R&D) investments (Ministry of Finance Finland 2023). Small and medium-sized and young companies are particularly affected by skills shortage. There are also differences between sectors (Czepek et al. 2015; Bellmann and Hübler 2014; Morris et al. 2020). Current occupational groups with the most registered job vacancies in Germany are transport and logistics, sales occupations and medical healthcare occupations (Statista Research Department 2024a). As a result of unfilled vacancies or unsuitable personnel, the shortage of skilled workers can lead to productivity losses and higher operating costs in the affected companies (Morris et al. 2020; Bennett and McGuinness 2009; Backman 2014; Sharma et al. 2016). Companies rate the shortage of skilled workers as one of the most significant business risks (Statista Research Department 2024b) and as a major obstacle to corporate investment (Brunello and Wruuck 2021). A sufficient supply of qualified skilled workers is crucial for an innovative and competitive economy (Burstedde et al. 2020). Overall, it can be assumed that a lack of required qualifications (or a lack of qualified skilled workers) can have a negative impact on economic development, as skills shortage can have a negative impact on earnings, productivity and innovation processes (Brunello and Wruuck 2021).

2.3 The impact of the skills shortage on regions and their development

Adding a regional perspective to the existing studies on the company level is relevant, because an analysis at regional level also sheds light on the question of whether the shortage of skilled workers is a problem that needs to be tackled at national or regional level. Existing differences in the shortage of skilled workers between regions can be compensated for through migration. If this works perfectly, the shortage of skilled workers is a supra-regional problem. If, on the other hand, regions with a greater shortage of skilled workers also have more significant negative effects on economic development, the problem of the shortage of skilled workers must be tackled on a region-specific basis. This question is at the heart of the paper's analysis and cannot be answered from the previous research findings on migration flows (Bauder 2006; Fiorentino et al. 2024; Schmutz et al. 2021) or from the literature on skilled workers that focuses on companies (König and Brenner 2022; Horbach and Rammer 2022; Bellmann and Hübler 2014).

Not every company and not every industry is affected by the skills shortage to the same extent or at all, and not all companies in a region are affected by the skills shortage (Burstedde et al. 2020; Morris et al. 2020). These considerations result in regional differences. However, there have been hardly any scientific analyses to date on the impact of skills shortage on the development of a region or a country. The migration of workers with higher education has a significant impact on strengthening the competitiveness and economic development of a region (Oliinyk et al. 2021). In this respect, workers migrating to regions with a shortage of skilled workers partially equalize the situation between regions (Bauder 2006), but many workers are less mobile (Fiorentino et al. 2024; Schmutz et al. 2021) and regions are affected to varying degrees by the shortage of skilled workers. Hertrich and Brenner (2023) list the shortage of skilled workers as one of several regional characteristics or barriers to innovation. In particular, their region type D "skill-shortage regions" tends to show economically weaker regions that are particularly affected by the shortage of skilled workers. König and Brenner (2022) conclude that companies in industrial clusters are less likely to suffer from skills shortages. Morris et al. (2020) find negative spillover effects for both skills gaps and skills shortages in nearby regions. Most experts and media assume a future negative impact of skills shortages on a country's gross domestic product (Müller 2022; Specht 2022), although there are also studies to the contrary (Astrov et al. 2016). Loss of efficiency and a suboptimal allocation of resources are seen as overall social costs (Brunello and Wruuck 2021; Garibaldi et al. 2020). The actual impact of skills shortages on the economic performance of a region and how skills shortages are reflected in economic and other indicators has not yet been extensively investigated and therefore the focus of this paper is on this research gap.

2.4 Hypothesis

The overarching key question of our study is: Are there problems in the economic development of a region caused by a shortage of skilled workers and, if so, what are the characteristics that indicate this? From the effects at company level listed in section 2.2 and the regional explanations described in section 2.3, it is possible to derive the expected effects of the skills shortage on regions, some of which are also discussed in the media (Specht 2022). This leads us to the following two hypotheses, which we examine in more detail in our analysis:

The shortage of skilled workers is slowing down the development and growth of some companies. It can therefore be expected that the shortage of skilled workers will have a negative impact on economic development at regional level (Specht 2022; Müller 2022).

H 1) Regional skills shortages have a negative effect on gross domestic product growth and investment activity in the affected regions.

Companies identify the shortage of skilled workers as a significant barrier to innovation (Rammer et al. 2020).

H 2) At regional level, R&D activity is declining in the regions affected by the shortage of skilled workers.

3. Methodology

We test the hypotheses set out in section 2.4 using two methods. These are firstly expert interviews with intermediaries (chambers and employment agencies) and companies (section 3.1) and secondly a vector auto-regressive (VAR) approach based on vacancy times (section 3.2).

3.1 Expert interviews

We conducted guided semi-structured expert interviews in 2022. The key questions of the questionnaire were deductively derived from the theory and are based on the research interest. Overall, the questionnaire was divided into four thematic blocks, one of which is relevant to this study. We asked the experts the following two questions, among others:

- 1) *Is the shortage of skilled workers a perceived problem in the labor market region?*
- 2) *What disadvantages are already resulting from the shortage of skilled workers today and are likely to result in the future, particularly for innovation processes in the labor market region?*

We did not define "skills shortage" per se in the interviews. When asked, we provided the definition listed above.

A total of 77 interviews with 78 experts from 10 German labor market regions (Bernkasel-Wittlich, Bochum, Coburg, Gera, Hanau, Leipzig, Luckenwalde, Lübeck, Mecklenburgische Seenplatte, Sonneberg) were conducted, transcribed and analyzed. As not all interviewees covered the topic of "skills shortage" and not every interviewee was able to answer every question, responses from 69 experts are relevant for the analysis (Table 1).

The criteria for selecting the experts were based on administrative/institutional responsibility (e.g. Federal Employment Agency), direct involvement (e.g. innovative companies) and the associated important function in the region. The anonymization of the data is important and necessary and was assured to the interviewed experts (Kruse and Schmieder 2014; Mayer 2018; Hopf 2019).

In order to obtain as many perspectives as possible on the assessment of skills shortage, we made sure that very different points of view were included in the analysis, so that the experts interviewed came from the following different stakeholder groups: Chambers of Industry and Commerce and Chambers of Crafts (chambers), companies, regional economic development institutions (funding), research institutions (research), the Federal Employment Agency (Employment Agency) and others (politics, innovation funding agency, regional management).

Table 1: Number of experts for each group.

Expert group	Research	Chambers	Development	Employment Agency	Companies	Other
Number of experts	8	14	17	8	15	7
Percentage	11,59%	20,29%	24,64%	11,59%	21,74%	10,14%

The qualitative content analysis according to Mayring (2019, 2022) was carried out to ensure a systematic data analysis. The expert interviews were transcribed and analyzed using MAXQDA (Kelle 2019). A category system was created partly de-ductively from theory, with some inductive changes from the interview material (Kromrey et al. 2016). The text passages from the expert interviews were then assigned to the various categories from the category system, and new categories were also created from the material. The standardized coding procedure enables us to carry out comparative evaluations of the material (Kelle 2019; Mattissek et al. 2013). In order to reduce subjectivity, mainly superordinate categories are analyzed.

3.2 Statistical analysis

In order to examine the regional impact of skills shortages on various economic variables, we apply a VAR-LiNG approach (Lacerda et al. 2008; Moneta et al. 2013; Ciarli et al. 2019). A vector auto-regressive (VAR) model explicitly considers endogenous dependencies between the variables, so that the endogeneity problem is strongly reduced. Furthermore, we use within VAR panel regressions with individual and time fixed effects, which further reduces endogeneity. Hence, it can be assumed that endogeneity plays a minor role and the identified relationships can be assumed to reflect causal relations. In addition, we use the so-called VAR-LiNG approach, which does not predetermine the causal order of variables but identifies this order from the empirical data.

The analysis is conducted for 254 labor market regions in Germany. Labor market regions (LMR) are defined in Germany by aggregating those administrative districts with a high commuting activity between them into joint regions. Since we study effects of labor market conditions, labor market regions provide an adequate observation unit. We use the LMR definition in Germany by the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR) from the year 2017, which identified 258 labor market regions¹. In the case of two of these labor market regions, the underlying administrative districts have been merged in the meantime, so that we also merged them for our analysis. Three regions had to be excluded because of missing data on investments. Hence, our analysis is conducted including 254 regions.

We use data from different sources as described in Table 2. We use vacancy times for skilled workers to represent skills shortages in regions. A skilled worker is a qualified worker who has completed vocational training, completed advanced training, completed a degree program or has a comparable multi-year qualification (Burstedde et al. 2020). All data is available on the level of administrative districts and aggregated to the labor market regions by us. We use data for the years 2008 til 2021. Regional spillovers are considered by using spatially weighted average values of all our variables as control variables in all regressions. A logistic distance decay function is used (Scholl et al. 2016) to calculate spatially weighted average values, where the distance between regions is approximated by the average driving times between people's location in the two regions.

Table 2: Description of the used data.

Variable	Description	Source
Vacancy time	Average vacancy time in days for jobs that are advertised via the Federal Employment Agency and belong to the categories skilled workers (jobs with qualified training), specialists (jobs with master craftsman or technician training or a university degree) and experts (jobs with a higher academic degree)	Federal Employment Agency (IAB)
Employment	Number of employees per inhabitants	
Qualification	Share of all regional employees that hold a university degree	
Wages	Median of all wages of full-time employees	
GDP	Regional Gross domestic product per inhabitant	German Statistical Office
Investments	Investments in the primary and secondary sectors per inhabitant	
Migration	Net-migration: difference between within-country incoming and outgoing migration per inhabitant	
R&D employees	Number of R&D employees per inhabitant	The Stifterverband

¹ There is a new classification, but the one from 2017 fits better with the time period that we analyse and is still available on <https://www.bbsr.bund.de/BBSR/DE/forschung/raumb Beobachtung/downloads/archiv/download-referenzen.html>

We apply the VAR approach only to those variables that show a strong endogeneity. To this end, we first examined the relationships between the variables by conducting panel regressions for each in dependence to all other variables. It resulted that GDP, employment, qualification, wages, investments and R&D employees explain each other's developments very well, while including the other variables does not increase the fit significantly. Hence, we declare migration as pure outcome variables, without considering effects of this variable on the other variables. Vacancy time is only used as input because we intend to examine the impact of this variable on all other variables.

The VAR approach allows to identify not only the direct effects of one variable on other variables, but also the indirect effects that are transmitted via the other variable included in the analysis. Therefore, the findings are presented by so-called impulse response functions (IRFs). These functions show how one variable is changed on average over the next years as a reaction to a change of another variable in one year. To calculate these impulse response functions, a change of one variable (in our case a change in the vacancy time) is assumed and the effects on all other variables in the next 25 years are simulated using the estimated equations. Confidence intervals for the IRFs are calculated by a bootstrap approach, repeatedly (200 time) drawing random samples of the real regions and conducting the analysis for these samples. In the following we study the impulse response functions for a change in the vacancy times. This means that we study how other variables are changed if the vacancy time is increased in one year (called the reference year 0) and then returns to the usual value the years after this year.

4 Regression results

4.1 Effects of skills shortage on economic activity

According to Hypothesis H1 we expect that increases in vacancy times, which signify increasing skills shortage, have negative impacts on economic growth and investments. Our analysis leads to impulse response functions that confirm this hypothesis (Figure 1). Both, GDP and investments, react negatively to an increase of skills shortage. Hence, our study confirms on a regional level the findings obtained on the company level. This implies that skills shortages on the regional level cannot be compensated by migration from other regions. As a consequence, skills shortages have to be tackled on the regional level.

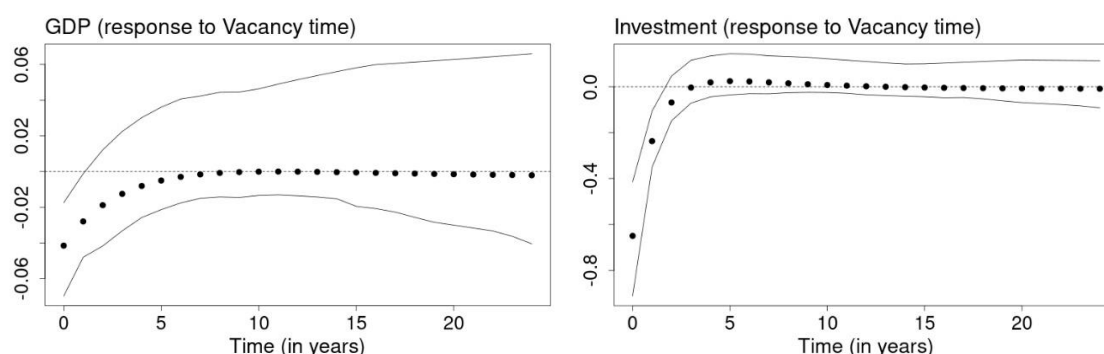


Figure 1: Impulse response functions for the reaction of GDP and Investments on an increase in vacancy times (dotted line: estimated IRF; lines: 95% confidence intervals).

The IRFs provide further information: The negative effects are for both, GDP and investments, only significant in the first two years. Both variables recover quickly. This means, if the skills shortage is a temporary phenomenon, the economy recovers quickly and returns to the usual values 3 to 6 years later. Instead, if skills shortage is a permanent situation, a clear and permanent reduction of economic activity results. Furthermore, the IRFs show that the reaction of investment is much stronger (reactions are measured as multiples of one standard deviation of the variables variation between German regions). Investments are strongly reduced due to

regional skills shortages. It seems (although not significant) as if some compensation occurs after 5 years. Some investments might be postponed.

Related to the above findings, we also find a significant decrease in employment as a reaction to skills shortage (Figure 2). Interestingly, the impact is similar to the one on GDP in size but much more long-lasting. The share of workers with a university degree (qualification) reacts delayed but very long-lasting on skills shortages. It seems that the lack of skilled workers can be first compensated (maybe by migration), but finally leads to a clear reduction of highly educated workers in the region.

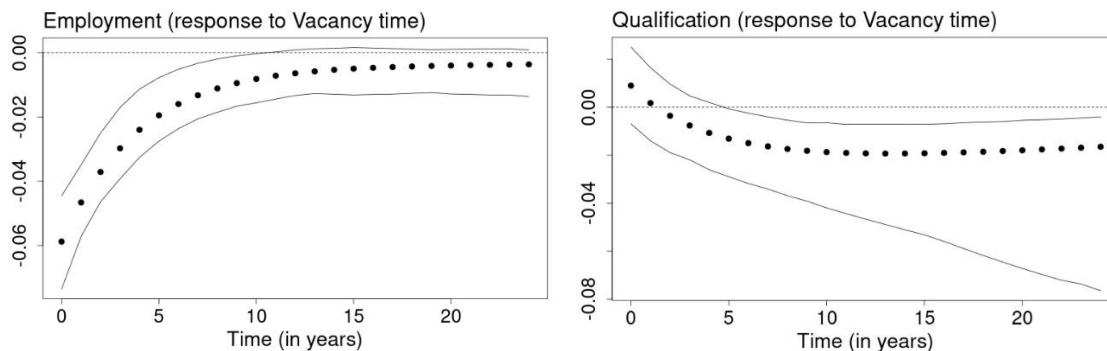


Figure 2: Impulse response functions for the reaction of employment and qualification on an increase in vacancy times (dotted line: estimated IRF; lines: 95% confidence intervals).

4.2 Effects of skills shortage on innovation activity

Hypothesis H2 states the expectation that also innovativeness is decreased by skills shortages in regions. Our result does not confirm this hypothesis. We do not find any significant reaction of R&D employment on skills shortage (Figure 3). This is surprising given the findings on the firm level in the literature (Rammer et al. 2020) and the clear effects on the economic activity identified above. We examine this finding more comprehensively in the next chapter with the help of the expert interviews.

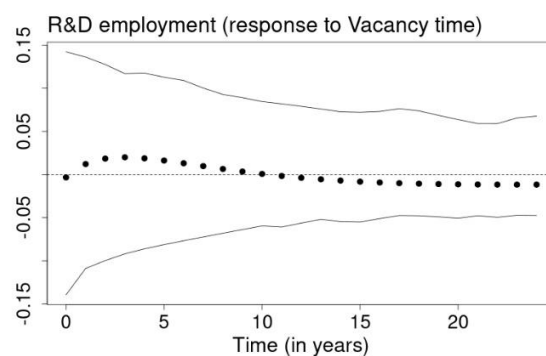


Figure 3: Impulse response functions for the reaction of R&D employment on an increase in vacancy times (dotted line: estimated IRF; lines: 95% confidence intervals).

Potential explanations for the lack of a significant impact of skills shortage on R&D activities might be that firms can compensate this by paying higher wages and attracting people from outside the region. This might be easier in case of R&D staff and highly qualified employees, since those are more willing to migrate for jobs. The identified effects of skills shortage on wages and migrations support such an interpretation (Figure 4). Interestingly, the findings show that the migration increases just to fill the lack of employees and does not lead to a more permanent increase in migration flows. In contrast, wages are increase in a more long-lasting way.

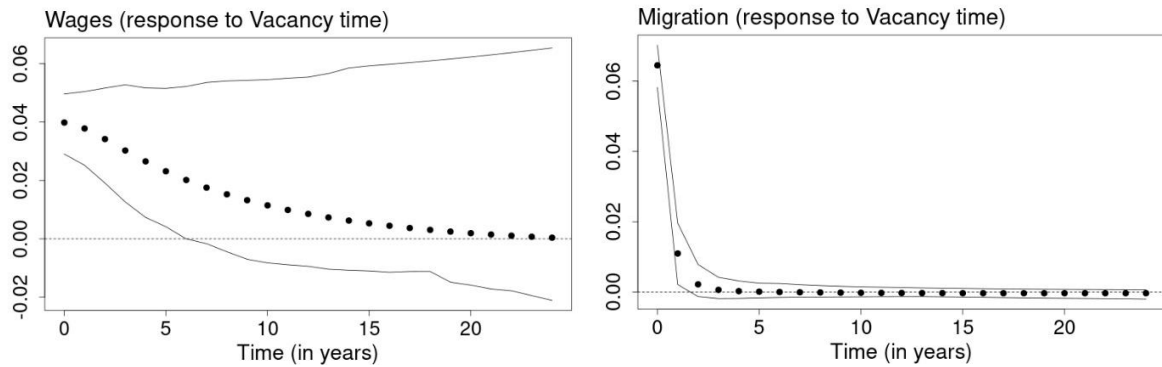


Figure 4: Impulse response functions for the reaction of wages and migration on an increase in vacancy times (dotted line: estimated IRF; lines: 95% confidence intervals).

5 Experts' explanations

The statistical analysis has confirmed Hypothesis H1 but not Hypothesis H2. Therefore, we use expert interviews to dig deeper in the reasons behind these findings, especially the effects on innovation activity. We start with the general assessment of the experts (Section 5.1) and then focus the problems with innovation processes resulting from the shortage of skilled workers (Section 5.2).

5.1 The shortage of skilled workers is perceived as a problem

A total of 62 experts answered the question of whether the shortage of skilled workers is a perceived problem in their labor market region (see section 3.2). The experts' answers are relatively clear: 57 experts see skills shortage as a problem in their region, which is 92 percent of all experts interviewed. Table 3 shows the distribution of the assessment across the various expert groups.

Table 3: Overview of the expert opinions

Expert group	Research	Chambers	Development	Employment Agency	Companies	Others
Number of experts who answered this question	8	14	13	8	12	7
Experts perceiving skills shortage as a problem	7	14	12	8	10	6
Experts not perceiving skills shortage as a problem	1	0	1	0	2	1

Interestingly, experts from companies are slightly less likely to perceive skills shortage as a problem. The reasons given are mainly based on the fact that the shortage of skilled workers is not (yet) widespread and (or) does not affect all sectors and professions, as the following statements show:

“Well, I would say not at the moment. Leipzig has long been the red lantern when it comes to unemployment rates in Germany. The problem is increasingly disappearing. Thus, we no longer have a problem of structural mass unemployment. But the shortage of skilled workers is coming, but it's not there yet. That is my perception. There are fewer and fewer unemployed people. But it's still not so easy for students and younger trainees to find a really well-paid job in Leipzig” (Interview_Research Institution 2021a:3).

and

“There is no nationwide shortage of skilled workers in NRW, but in individual occupational fields, and the trend is rising” (Interview_Company 2021b:14).

5.2 Disadvantages of skills shortage for innovation processes

We also asked the experts what disadvantages result from the shortage of skilled workers, particularly for innovation processes in the labor market region. Many experts described negative effects of the skills shortage on innovation in the region. However, there is also a smaller number of experts who stated that the shortage of skilled workers has no disadvantages for regional innovation processes. The main line of argumentation among these experts is that there is no shortage of skilled personnel for innovation. It is argued that there is an over-academization and therefore innovation projects are not affected by the shortage of skilled workers, as the labour market does not need the many academics. One stakeholder from a business development agency describes this as follows:

"We have a very, very high level of academization in the society, but this is really also to be seen nationally and many academics that the labor market, at least our labor market in that sense, does not necessarily need at the moment and in abundance" (Interview_Regional Economic Development Institution 2021b:35).

In this respect, there would be a sufficient number of innovation actors and a "relatively high skilled worker/engineer base" (Interview_Regional Economic Development Institution 2021a:14), but the "qualified skilled workers (...) would gradually run out" (Interview_Regional Economic Development Institution 2021b:35). These arguments fit very well to the above statistical findings: Qualification (measured as the share of workers with a university degree) does not immediately react on skills shortage, but only with some delay. The experts' comments can be interpreted such that due to a lack of qualified workers companies lower their requirements to fill the position, leading to a medium- and long-term reduction of qualification. Qualifications needed for innovation activities seem to be sufficiently present or willing to migrate, at least in the past.

Another stakeholder from business development describes the line of argument described as follows:

"So, if we had a shortage of skilled workers in this area, then there would certainly be logical disadvantages, because every development takes place mainly in people's heads. But our shortage of skilled workers is more concentrated in other areas, like everywhere in Germany, in the care sector" (Interview_Regional Economic Development Institution 2021c:35).

However, the majority of the experts surveyed listed various disadvantages to the innovation process due to the shortage of skilled workers. Nevertheless, the experts' statements often remain very general and reasons are given that will only become apparent in the future. Clear current regional impacts on innovation activity are not given by the experts; much remains hypothetical and is projected into the future. Hence, although the statements of the experts seem to contradict our statistical findings on first view, they are quite in line with the statistical findings as shown below.

However, the experts' statements offer some additional insights. Therefore, we structured their statements into **four lines of argument**, which are discussed separately and in detail below.

1. Innovation culture is being lost due to the shortage of young workers

The innovative strength of a society often depends on young people, on their creativity and their other view of the world. Due to demographic change, this source of innovation seems to be increasingly drying up. "But there are no young people coming up. And that means there is simply a lack of good and smart ideas," is how one expert from the chambers describes the situation (Tran-skript_4_16.06.21_IHK_1). Overall, the shortage of skilled workers minimizes the culture of innovation, as young people bring specific characteristics to companies that are fundamental for innovation. "So, in this respect, there is a bit of a lack of, well, how should I put it, actual ideas" (Transcript_4_30.06.21_WF_AFA_4, pos. 28), as one stakeholder from the employment agency addresses the problem. According to another respondent from a research institution, older people are more vulnerable than young people:

"too slow. Too late. Not the innovative ideas, the lateral thinkers, just trying something out, accepting risks, putting a few euros in the sand, breaking out of the usual rut. So, that's already a problem" (Interview_Research Institution 2021c:69).

This sheds light on an aspect that the statistical analysis is not able to detect: While innovation activity is not directly affected, the workers become older especially in economically lagging regions, which might impact negatively on the innovation activity in the long run.

2. Decreasing quality of applicants

Experts also complain about a lack of qualified applicants, which has a negative impact on innovation efforts. "If we don't manage to keep the brightest minds in the region or attract them here, then we definitely won't be able to keep up with the other regions," warns a stakeholder from a company (Interview_Company 2021a:21). And there is a lack of quality among the available applicants, which could also reduce innovativeness in the long term, as a stakeholder from the employment agency describes:

"Are these the ones where I say, at the moment you're making a fool of yourself everywhere, I notice it with my wife at the Chamber of Industry and Commerce, so what they're dragging through the final exam at the moment, sorry, no offense meant, simply because we need the people. In other words, there's a risk that the standard will drop" (Interview_Employment Agency 2021:133).

A significant skill mismatch is in line with other studies (Sevinc et al. 2020). The exodus of young talents to other regions or even abroad and the resulting decline in regional innovation compared to other areas is perceived as a problem. The declining quality of applicants makes it difficult for local companies to find the right employees for their innovative projects. The difficulty in finding highly qualified employees not only means a bottleneck in human resources, but also has a direct impact on the ability of companies to implement innovative projects. One player from the business development sector describes the problem as follows:

"Well, the fact that many companies or the majority of companies still have a low response to their job advertisements alone means that the selection potential is logically no longer quite as great to really fill the positions with the best people who fit into the company, the team and the job, and logically this also has an overall effect on the entire company and possibly also on the innovation processes, so that a certain backlog could possibly be recorded there" (Interview_Regional Economic Development Institution 2021e:12).

Again, this is an aspect that will slowly develop an impact on the innovation activity of firms and cannot be detected by the statistical analysis.

3. Slowdown of regional development

In line with the statistical findings many experts state that the firms' production activity is negatively influenced by skills shortage in first place and not the innovation activity. The inability to recruit suitable skilled workers can become a significant business risk, even leading to the closure of a company, as one player reports:

"That they will not make any expansion investments at the site. Or are aiming to close down. Because they can't get any more staff" (Interview_Chamber of Industry and Commerce 2021a:2).

One player from the business development sector describes the problem as follows:

"Well, I don't think I've ever actually heard anyone say that I can't think about and implement new ideas here because I don't have the people I need. Instead, the great valley of misery is really that I need people to be able to work properly at all. So we're simply talking about a completely different quality" (Interview_Chamber of Industry and Commerce 2021c:49).

Due to the overall low staffing levels in companies and the described focus on day-to-day business, the innovativeness of companies is stated to be also suffering. "The topic of innovation is increasingly taking a back seat when it comes to keeping the company running," explains an expert from a chamber (Interview_Chamber of Industry and Commerce 2021b:31).

This means that skills shortage implies that fewer resources can be invested in innovation and investments in the expansion of production capacities cannot be made. "Due to the shortage of skilled workers, understaffing is simply the order of the day at local companies and this naturally inhibits any potential for innovation," states one expert (Interview_Regional Management 2021:53). Many experts see the overall lack of skilled workers impacting also innovation activity. One stakeholder from an economic development agency describes the disadvantage for companies as follows:

"This [shortage of skilled workers] is of course a brake on growth somewhere. And then I would perhaps put it this way: At the moment when I only have a limited capacity of skilled workers, I have to deploy them in the way that serves me best. That means the welder has to weld to get the job done and not to make the prototype" (Interview_Regional Economic Development Institution 2021d:39).

However, the argument that skills shortage in general impacts also on the innovation activity is not backed by the statistical results above and the opinion on this seems to be quite different among the experts.

4. Outsourcing and emigration harm the region in the long term

The shortage of skilled workers threatens to force companies in the region to relocate their resources abroad or even close sites. "In the worst case scenario, this shortage of skilled workers will lead to things being outsourced. In other words, some things are even outsourced abroad," describes a stakeholder from a research institution (Interview_Research Institution 2021b:42). Rising personnel costs and the high cost of recruiting staff, or the lack of suitable specialist staff, are prompting companies to look for alternative solutions. The migration of companies reduces the innovative strength of the region in the long term. Another stakeholder describes the problem as follows:

„that the companies that can do it are also moving to places where there are more skilled workers. They look around. And if I have to go through a huge fuss every time I have to recruit someone in the company until I find someone, that doesn't help the processes" (Interview_Research Institution 2021c:66).

This is in line with our statistical finding that wages increase and that this effect is long-lasting.

6 Conclusion

Our analysis confirms that skills shortage in Germany has negative impacts on the economic development of regions. Using a vector auto-regressive model, which is able to detect causal impacts, we find that skills shortage has significant negative impact on gross domestic product (GDP), employment and investments, but not on research and development (R&D). The expert interviews show that many of the experts interviewed describe negative effects of the skills shortage on innovation in the regions. However, the experts' statements often remain very general and reasons are given that will only take place in the future. They describe that the R&D staff becomes older and less qualified with time, which will result in a decrease of innovation output in the long run. Furthermore, they see an increasing impact of the overall skills shortage also on innovation activity. At the moment, this impact is compensated by an over-academization in Germany and the high mobility of highly-educated people

Furthermore, our results indicate that the skills shortage is a problem that needs to be addressed at the regional level (Corradini et al. 2023), because intra-national migration is not able to compensate for the strong negative economic effects on the regional level. This shows the high relevance of our results for political decision-makers at the regional level. Policies to address skills shortages focus primarily on adapting the education and training system to the needs of the labor market. These are in particular improvements in career and vocational guidance (Brunello and Wruuck 2021). There are certainly still hidden reserves and untapped potential in the German labor market, but our results show that mainly the quality and number of

available workers in the respective regions form a problem. Therefore, specific regional measures to attract more skilled workers to the region should be implemented at regional level.

Our analysis shows already strong negative impacts, especially on investments. Which is even more damaging for a region in the long term. But it also shows that the current impacts are only the beginning. For example, innovation activities are so far not (or not significantly) influenced but will be in the future. Migration within Germany is not able to solve that problem, as our analysis shows. Other researchers also show very positive effects of skilled immigration (Oliinyk et al. 2021). Hence, skills shortage can also be talked at the national level, e.g. by improving the national framework conditions and launching certain political support programs for skilled immigration.

In addition, our results can serve as a starting point for further regional analyses in order to better determine and understand the effects of the skills shortage in the regions. Our results show that the challenges are intensifying, which should lead to greater relevance in the research community. Our results only refer to Germany, so it is interesting and important to know whether a similar analysis at European level would come to similar results or whether there are certain country-specific mechanisms. Further research is needed to provide the best possible support to regions affected by the skills shortage and to make them more resilient.

Conflicts of Interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the result.

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