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COVID-19 and the labour market: What are the working conditions like in critical jobs?

Matthias Dütsch[1]

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The COVID-19 pandemic has focused public attention on occupational groups that ensure the maintenance of critical infrastructure, the provision of medical care and the supply of essential goods. This paper examines working conditions in critical jobs based on representative data from the German BAuA Working Time Survey 2019. Our analyses reveal that essential workers are more likely to be female, to work in specialist activities and in security, cleaning, transport and logistics as well as health care occupations. Regarding working conditions, essential workers are paid comparatively less and are more physically proximate to others at work. They more often work atypical hours, such as day and night shifts and on weekends, and have less working time autonomy. Additionally, critical jobs are characterised by muscular and skeletal strain due to working positions and carrying heavy loads significantly more often. Thus, our findings strongly suggest that work-related risks accumulate in critical jobs.

Content

1 Introduction

The COVID-19 pandemic has dramatically affected and changed individuals' social and economic lives. In many countries, numerous requirements, such as the wearing of a mask, have been put in place, distancing measures have been established and recommendations for avoiding social contact to protect against infection have been communicated in order to contain the virus. In the course of implementing these containment measures, the socalled critical sectors of the economy and critical occupations have become the focus of political and public attention. Government institutions worldwide drew up lists of critical sectors and occupations that are very similar in their composition, since workers in these sectors ensure, among other things, the maintenance of systemically relevant infrastructure as well as the provision of medical care and nursing services or the supply of essential goods (see, e.g., for the US: CISA (2020), for the UK: CPNI (2021), and for

[1] Secretariat of the German Minimum Wage Commission, c/o Federal Institute for Occupational Safety and Health (BAuA), Nöldnerstraße 40-42, 10317 Berlin, Germany; e-mail: *matthias.duetsch@geschaeftsstelle-mindestlohn.de*

Germany: BMAS (2020)). Unlike other employees who were asked to isolate themselves, work from home, and reduce their social contact at work, essential employees were provided with support measures, such as emergency childcare, so that they could continue to perform their jobs (ibid.).

By examining, in particular, wages and physical proximity in critical occupations or industries, recent empirical research has indicated that working conditions in critical jobs are less favourable and have become even more hazardous in the wake of the pandemic. However, by referring to theoretical approaches to segmented labour markets (Hendry 2003; Osterman 2011; Kaufman 2013) and research on the quality of work (Kalleberg 2011; Howell and Kalleberg 2019), we argue that it is necessary to gain insights into a broader range of working conditions since favourable and unfavourable working conditions are often found in a cumulative manner (ibid.). Beyond wages and physical proximity, working time patterns and physical working conditions are two additional crucial considerations. The former is important, as working time arrangements influence everyday life (ILO 2018) and the organisation of work and family life (Howell and Kalleberg 2019). Both became even more significant when the measures to contain the COVID-19 pandemic were in effect, since parents, and women in particular, had to engage in childcare and homeschooling to a much greater extent than before. Unfavourable working hours also adversely affect individuals' health. Furthermore, a wide range of studies have found physical working conditions to be important for individuals' working lives. Physically demanding labour negatively influences health outcomes and leads to health inequalities and health-related job loss.

Against this backdrop, this paper aims to perform a more comprehensive analysis of working conditions in critical jobs and to contribute to recent research in the following ways. First, we conceptually frame the public and academic discussion about working conditions in critical occupations by arguing that this debate can be linked to theoretical approaches to segmented labour markets. Second, we describe the socio-demographic characteristics and structural determinants of critical occupations in order to enable policy decisions that protect and meet the needs of essential workers. Third, we extend recent research on critical occupations by following Kalleberg's (2011, p. 5) note that working conditions comprise multidimensional bundles of rewards and burdens. Therefore, we analyse wages, a classical dimension of inequality, and physical proximity at work, which we consider to be a new and emerging stressor due to the COVID-19 pandemic, as well as working time patterns and physical working conditions. Understanding which population strata are most affected and gaining deeper insights into the working conditions in critical jobs is crucial because research has examined the longerterm effects of past crises on labour market outcomes (Killewald and Zhuo 2019). Furthermore, employment-related exposure to SARS-CoV-2 endangers not only workers but also their household members (Selden and Berdahl 2020).

The empirical analyses are based on the German Federal Institute for Occupational Safety and Health (BAuA, for its German acronym) Working Time Survey 2019, which was conducted shortly before the beginning of the COVID-19 pandemic and was therefore unaffected by it. The Working Time Survey is a representative study that includes detailed information on approxi-mately 9,500 individuals from all industries. It is a unique dataset since it contains individuallevel information on wages, physical proximity to others, working time patterns and physical working conditions, as well as the socio-demographic, job-related and structural characteristics of workers and their jobs. The empirical investigation is conducted in three steps. First, a descriptive analysis of the data is presented. Second, binary logistic regressions are performed to determine the likelihood of working in a critical job and, thus, to identify the groups of employees concerned. Third, in various regression estimations, the relationships between critical jobs and working conditions are investigated in order to assess the possible accumulation of risks.

2 State of the research

Since the beginning of the pandemic, the literature on the groups of workers affected by the pandemic, as defined by their socio-demographic characteristics, as well as on the consequences of COVID-19 for individuals and households has been growing rapidly. However, to our knowledge, only a few research papers to date have focused on systemically relevant occupations.

Blau, Koebe and Mayerhofer (2020) studied the US labour market and drew on the federal guidelines of the Department of Homeland Security (DHS) and the Cybersecurity and Infrastructure Security Agency (CISA), identifying 194 out of 287 total NAICS industry categories as essential. Additionally, the study identified those frontline workers who compose a subcategory of essential workers: those in occupational groups where a third of workers or fewer can feasibly work from home. Both constructs were mapped to microdata from the 2017 and 2018 American Community Survey. A descriptive comparison of the gender, race, educational degrees and hourly wages of essential and frontline workers revealed that the broader group of essential workers tends to mirror the average demographic and labour market characteristics of all workers. In contrast, the narrower group of frontline workers is, on average, less educated, earns lower wages, and is composed of more men, more disadvantaged minorities, especially Hispanics, and more immigrants. Kane and Tomer (2021) drew on the 4-digit NAICS industries related to the list of essential critical infrastructure workers and on employment data for each industry from the Bureau of Labor Statistics and also defined a subgroup of frontline workers. Their descriptive results indicated that frontline workers earn lower wages and are more frequently required to be physically present at their workplace. Frontline workers also tend to be less educated than other essential workers and the wider US workforce. Comparatively more often, essential workers are males working in construction, manufacturing, or skilled trades, while female employees are much more concentrated in other essential occupations, such as health care, education, and service activities. Employing household data from the 2018 American Community Survey (ACS), which is a random sample of US households, and the DHS list of essential critical infrastructure workers, McCormack et al. (2020) descriptively estimated that 25 percent of essential workers' households are low income.

Looking at the German labour market, Koebe, Samtleben, Schrenker and Zucco (2020) investigated the social prestige of and average wages in critical occupations. They used the German Socio-Economic Panel (GSOEP), a representative household survey, and classified "first hour" and "second hour" critical occupations based on the list issued by the federal state of Berlin. The list of firsthour critical occupations was published in Berlin on 17 March 2020 and was expanded approximately one month later to include the list of secondhour critical occupations.[2] The data were operationalised at the 3-digit occupation classification level. By performing descriptive analyses, Koebe et al. (2020) found that essential employees are more likely to be female, to have below-average social prestige and to report below-average wages. These findings apply especially to first-hour critical occupations. Lübker and Zucco (2020) relied on German linked employer-employee data in their study and analysed employees in critical economic sectors. Applying logistic regressions, the authors revealed that women are more likely to work in critical infrastructure than men. This is also true for part-time workers and employees with technical jobs. By contrast, individuals without a university degree are slightly less likely to work in a critical sector. An assessment of the wages of full-time employees did not indicate systematic differences between critical and non-critical sectors.

The above literature review on critical labour during the COVID-19 pandemic shows that many research papers have provided only descriptive evidence. The findings, both for the US and for the German labour market, do not indicate a clear pattern regarding the socio-demographics of essential employees. However, essential employees seem to earn comparatively lower wages in poorly valued jobs and often perform work that requires physical proximity to others.

3 Social inequalities, working conditions, and the COVID-19 pandemic

A theoretical rationale for the differences in working conditions between critical and non-critical jobs is missing. Against the backdrop of recent studies that have identified apparently coinciding risks in critical jobs, we draw on newer theoretical approaches to human resource management that explain labour market segmentation (Hendry 2003; Osterman 2011; Kaufman 2013). Approaches to human resource management assume imperfect labour markets and incomplete labour contracts. They emphasise that segmentation, and thus inequalities in the labour market, depend on employees' and employers' bargaining power as well as on the social and structural conditions that frame social actions within the employment system (ibid.).

[2] The critical occupations of the "first hour" consist of those activities that have been considered systemically relevant since the beginning of the Corona crisis.

Since employment relations are determined by the relative power of employers and employees to control tasks, negotiate the conditions of employment, and terminate employment, various aspects of job quality covary. If employers are interested in binding employees to the company for a longer period of time, they can achieve this through offering more secure and more highly paid jobs, better working conditions and further training opportunities. This creates closed positions in primary segments of the employment system (Hendry 2003; Osterman 2011; Kaufman 2013). By contrast, in more open and, therefore, secondary segments of the employment system, the problem of worker availability is quantitative only and is thus limited to the number of employees in external labour markets. Employees in open employment systems have little power of action in the labour market due to the competitive situation in their occupational field and the lack of representation for their interests. Therefore, this segment of the employment system is characterised by comparatively low wages and unfavourable non-economic working conditions (ibid.). In fact, scholars could examine several individual, job-related and structural factors, such as gender, age, the type of work, the existence of work councils, firm size or economic sector, which are strongly associated with individuals' positions in the primary or secondary labour market segments (Hudson 2007; Lucifora and Salverda 2009; Howell and Kalleberg 2019). Because working conditions are composed of multidimensional bundles of rewards and burdens (Muñoz de Bustillo et al. 2011; Kalleberg 2011), we consider four crucial types of working conditions in what follows.

First, the core dimension of job quality is certainly wages; wages are also regarded to be the most straightforward attribute to measure (Muñoz de Bustillo et al. 2011; Howell and Kalleberg 2019). Wage inequality has been shown to be substantial and to have risen in many countries (Autor, Katz and Kearney. 2008; Bol and Weeden 2015). The increased inequality among occupations and the associated heterogeneities across workplaces and firms (Card, Heining and Kline 2013; Biewen, Fitzenberger and de Lazzer 2017) point to increased segmentation in the labour market. In terms of working conditions, the sustained receipt of low wages is a serious issue because low wages have been shown to negatively influence, amongst other outcomes, individuals' work satisfaction (Diaz-Serrano and Cabral 2005) and health (Kim and Leigh 2010; Leigh and Du 2012).

Second, as a result of the COVID-19 pandemic, epidemiological risk at work is considered to be a crucial component of working conditions, which, however, is not evenly distributed across workplaces and employees (Avdiu and Nayyar 2020; Basso, Boeri, Caiumi and Paccagnella 2020; Dingel and Neiman 2020). Workers more highly exposed to aerosols due to a high degree of social interactions at work with customers, clients, and persons in need of care report deteriorated physical and mental health outcomes and face a greater risk of SARS-CoV-2 infection (Mhango, Dzobo, Chitungo and Dzinamarira 2020; Sanghera et al. 2020). In contrast, in the case of home office work, work-related face-to-face interactions can be avoided, which reduces exposure to aerosols and therefore the risk of infection (Dingel and Neiman 2020).

Third, a further important aspect of working conditions is working time, as the ILO recently emphasised: "Working time, perhaps second only to wages, is the working condition that has the most direct impact on the day-to-day lives of workers" (ILO 2018, p 2). It is especially relevant to the organisation of work and family life (Howell and Kalleberg 2019). Working time arrangements became even more significant when the measures to contain the COVID-19 pandemic were in effect, since parents, and women in particular, had to engage in childcare and homeschooling to a much greater extent than before (Alon et al. 2021). Furthermore, working time is crucial to employees' health. Long working hours, including overtime hours, are negatively correlated with physical as well as psychological health (Bannai and Tamakoshi 2014; Kivimäki et al. 2015) and are positively correlated with the risk of workplace accidents (Dembe, Erickson, Delbos, and Steven Banks 2005; Fischer et al. 2017). Regarding atypical working hours, studies have found negative health effects when work has to be performed during socially valuable times – on Sundays, for example (Wirtz, Nachreiner and Rolfes 2011) – and during night shifts in particular (Costa 2003). Research has also provided evidence that a lack of job control regarding the flexibility of working hours, such as being on call or being expected to be accessible at all times, limits workers' individual autonomy and places demands on employees, constituting stressors that negatively affect health (Väänänen et al. 2008; Slany et al. 2014). During the COVID-19 pandemic, the greatly increased work intensity was reported as a risk factor for the mental health of medical and nursing staff (Godderis et al. 2020; Sanghera et al. 2020).

Fourth, physical working conditions are another important aspect of job quality (Muñoz de Bustillo et al. 2011). Research has indicated that poor physical working conditions cause severe health problems (Laakso-

nen et al. 2010; Holtermann et al. 2011) and health inequalities (Kaikkonen, Rahkonen, Lallukka and Lahelma 2009) and lead to health-related job loss (Sewdas et al. 2019). Work that primarily requires the use of the musculoskeletal system to accomplish its corresponding tasks is described as physically demanding (de Kok et al. 2019). Such jobs include handling manual loads (such as lifting loads), working in forced postures (such as standing, sitting, or bending the torso), working with increased exertion, and completing highly repetitive manual tasks. Numerous systematic reviews have demonstrated the link between physical strain at work and musculoskeletal disorders, which are very common health problems (Holtermann et al. 2011). The prevalence of musculoskeletal disorders is associated with high levels of anxiety, sleeping problems and overall fatigue among workers; such disorders are also related to workers' mental wellbeing (de Kok et al. 2019). Furthermore, physical stress causes, amongst other problems, cardiovascular diseases (Holtermann et al. 2011).

Against this backdrop, we focus on wages, physical proximity to others at work, working time patterns and physical working conditions to assess work-related risks in jobs crucial for the maintenance of social life during the pandemic. In the following section, we first describe the data, our operationalisation, and our method before presenting our empirical findings.

4 Data, operationalisation and method

Our analyses are based on data from the BAuA Working Time Survey 2019, a nationally representative study of the German working population. The survey was designed and commissioned by the BAuA (Wöhrmann, Brauner and Michel 2021). Data from 9,382 individuals were collected in computer-assisted telephone interviews between May 2019 and January 2020 and, thus, before the COVID-19 pandemic hit Germany. This is very important, as it ensures that respondents' answers about their working conditions were unaffected by the COVID-19 pandemic; thus, unbiased estimates can be assumed. To be eligible to participate, individuals had to be 15 years of age or older and in paid employment for at least 10 hours per week at the time of the interview. Employees who had interrupted their employment for longer than three months – for instance, because of maternity leave or periods of sickness – or who were engaged in vocational training or in military, civilian, or voluntary service were excluded. To compensate for survey-related selectivity and to ensure the representativeness of the data, weights are provided that adjust the BAuA Working Time Survey to match the basic figures from the 2018 Microcensus of the Federal Statistical Office (Häring et al. 2020). The advantage of the Working Time Survey is that for the first time, all relevant information on monthly wages, hours worked, physical proximity to others at work, working time patterns and physical working conditions is available within a single dataset, which additionally enables a variety of socio-demographic and structural factors to be included and controlled for.

Our variable of interest, which indicates whether an individual works in a systemically relevant occupation, was generated as follows. The categorisation of jobs as critical, indicated with a dummy variable (0=non-critical job; 1=critical job), is based on the list of systemically relevant sectors and occupations issued by the German Federal Ministry of Labour and Social Affairs (BMAS 2020). Two coders classified as critical occupations the occupations listed on the Classification of Occupations 2010 (KldB 2010) at the five-digit level by referring to the BMAS list. This double coding ensured high validity in the assignment of occupations. In addition, we compared our classification with that of Koebe et al. (2020), who, however, used the less differentiated three-digit level of the Classification of Occupations. We also compared our classification with another five-digit level classification of "systemically relevant occupations for supply and care", compiled by Burstedde et al. (2020). These comparisons made it possible to review the rationale behind the allocation of occupations.[3] To check the robustness of our results regarding the categorisation of critical jobs, we reestimated our analyses by using the three-digit classification of Koebe et al. (2020) and the alternative five-digit level classification of Burstedde et al. (2020) (see section 5.4).

Regarding the outcome variables, the Working Time Survey data allowed for calculating gross hourly wages based on gross monthly wages and weekly working hours. We obtained our figure for gross hourly wages

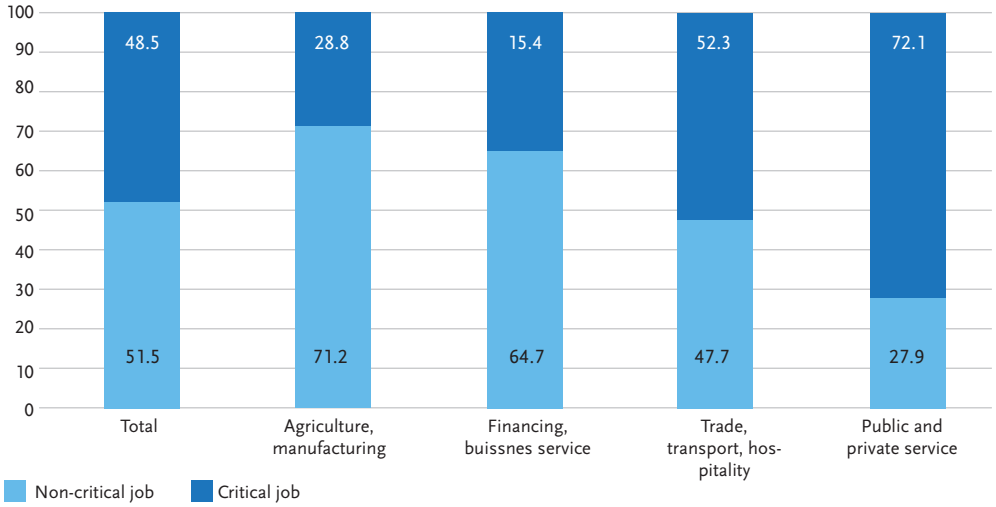
[3] The classification of critical occupations in this paper can be obtained from the authors upon request.

by dividing gross monthly wages by weekly working time, which was multiplied by 4.33.[4] Individuals who refused to answer the questions on wages and hours worked were dropped. These restrictions left us with a sample of 7,268 cases. The extent of physical proximity to others at work was assessed on the basis of three questions in the Working Time Survey: How often do you have direct contact at work with people or patients in need of care or assistance? How often do you have direct contact at work with guests, customers or clients? How often do you have direct contact at work with other people not employed by your employer? Respondents could indicate whether this was often, sometimes, rarely or never the case. We created a dummy variable coded with the value "1" to indicate frequent physical proximity when at least one of the three questions above was answered with "often". In all other cases, the value "0" was assigned, reflecting that there is sometimes, seldom, or never physical proximity to others at work. In recent research on physical proximity to others, home office work has been considered to be the exact opposite (Avdiu and Nayyar 2020; Dingel and Neiman 2020). Thus, we also include a home office indicator. Working time patterns are differentiated through measures of the duration of work, of atypical work hours (weekly overtime, shift work, weekend work) and of working time autonomy (being on-call or on standby regularly, making one's own decisions about breaks, being expected to be accessible in private life, having the possibility to separate work and private life). Physical working conditions are measured by indicators for muscular and skeletal strain (working in a standing position; working in a sitting position; kneeling, bending, or engaging in overhead work; lifting and carrying heavy loads) as well as for strain from the working environment (noise; bright, bad, or faint light; cold, heat, wetness, dampness, or draughts; the inability to influence one's work tasks).

5 Results

5.1 Descriptive result

Among the 31.8 million employees in our analysis sample, 15.4 million, or 48.5 percent, work in a critical job (figure 1).[5] Furthermore, critical jobs are found to varying degrees in the different sectors of the economy. Such jobs make up comparatively small shares of the "agriculture and manufacturing" (28.8 percent) and "financing and business services" (35.4 percent) sectors. A total of 52.3 percent of critical jobs are observed in the sector "trade, transport and hospitality"; the highest share of critical jobs is in the sector "public and private services" (72.1 percent).



Notes: Results are weighted. Source: Working Time Survey 2019; own calculations.

Fig. 1 Share of critical jobs (in percentages)

[4] The value 4.33 denotes the average number of weeks per month.

[5] The figures are very similar when we do not exclude individuals from our sample who refused to answer the questions on wages and hours worked; among the 35.6 million employees surveyed, 48.8 percent perform a critical job.

On average, employees in Germany earn 19.54 euros (table 1). Employees in critical jobs are paid 18.75 euros, which is slightly less than those in non-critical jobs, as non-critical employees are paid 20.29 euros. Among the ten lowest-paid critical occupations are cleaning services, (retail) sales occupations selling foodstuffs and doctors' receptionists and assistants (table 2).

Tab. 1 Descriptive statistics on wages, physical proximity, working time patterns and physical working conditions

		All observations		Critical workers		Non-critical workers	
		mean	SD	mean	SD	mean	SD
Wages	Hourly wage	19.54	11.513	18.75	12.025	20.29	10.953
Physical proximity at work	Physical proximity to others	0.57	0.494	0.68	0.466	0.47	0.499
	Home office work	0.20	0.691	0.12	0.12	0.27	0.779
Duration of work and atypical working hours	Weekly overtime (in hours)	3.22	4.171	3.34	4.517	3.11	3.811
	Working hours usually between 07:00 and 19:00	0.71	0.456	0.62	0.485	0.78	0.412
	Only early or late shift work: working hours not between 07:00 and 19:00	0.10	0.304	0.11	0.316	0.09	0.292
	Shift work without night work	0.10	0.299	0.13	0.337	0.07	0.254
	Shift work and night work	0.09	0.290	0.13	0.341	0.05	0.225
	No weekend work	0.59	0.491	0.48	0.500	0.70	0.459
	Work on Saturday	0.17	0.378	0.18	0.387	0.16	0.369
	Work on Saturday and Sunday	0.23	0.422	0.33	0.471	0.14	0.345
Working time autonomy	Regular on-call or stand-by service	0.09	0.293	0.13	0.339	0.06	0.236
	Make own decisions about breaks	0.34	0.628	0.30	0.629	0.37	0.625
	Not expected to be accessible in private life	0.63	0.483	0.59	0.492	0.67	0.471
	Partially expected to be accessible in private life	0.15	0.352	0.15	0.358	0.14	0.346
	Expected to be accessible in private life	0.23	0.419	0.26	0.439	0.19	0.396
	Separation of work and private life possible	0.73	0.455	0.70	0.460	0.76	0.448
Muscular and skeletal strain	Working in a standing position	0.53	0.509	0.64	0.481	0.43	0.515
	Working in a sitting position	0.55	0.507	0.49	0.520	0.61	0.488
	Kneeling, bending, working over head	0.16	0.368	0.19	0.392	0.13	0.341
	Lifting and carrying heavy loads	0.21	0.405	0.27	0.445	0.15	0.353

		All observations		Critical workers		Non-critical workers	
		mean	SD	mean	SD	mean	SD
Strain from the working environment	Noise	0.30	0.456	0.31	0.464	0.28	0.449
	Bright, bad, faint light	0.12	0.351	0.15	0.412	0.08	0.277
	Cold, heat, wetness, dampness, draughts	0.24	0.460	0.29	0.495	0.19	0.419
	Can influence the work tasks that must be carried out	0.35	0.581	0.33	0.586	0.37	0.575

Notes: Results are weighted. Source: Working Time Survey 2019; own calculations.

Furthermore, table 1 shows that approximately 57 percent of all jobs involve physically proximate activities. Compared to employees in non-critical jobs, those engaged in critical jobs are 21 percentage points more likely to work physically proximate to others. Home office work, which ensures distance from others while working, can be performed by 20 percent of employees; however, this proportion is significantly lower for essential employees (12 percent) than for non-essential employees (27 percent). Regarding the duration of work, weekly overtime is slightly higher among those in critical jobs (3.34 hours compared to 3.11 hours). Shift work and night work represent atypical working hours. In this respect, normal working hours during the day (between 07:00 and 19:00) are less common in critical jobs (62 percent) than in non-critical jobs (78 percent); however, rotating shifts without and with night work are approximately 6 and 8 percentage points more common in critical jobs, respectively. There are also crucial between-group differences with regard to weekend work. Working on both Saturdays and Sundays is much more common among essential employees (33 percent) than among non-essential employees (14 percent). Working time autonomy is lower among essential employees because they are more regularly on call or on standby (13 percent compared to 6 percent) and are less able to make decisions about their breaks themselves (26 percent compared to 19 percent). In addition, essential employees are expected to be accessible for workrelated matters in their private lives more often. Regarding muscular and skeletal strain, essential employees perform their work in a standing position (64 percent compared to 43 percent) or in a kneeling, bending, or overhead position (19 percent compared to 13 percent) more often and must lift and carry heavy loads more often (27 percent compared to 15 percent). Strain from the working environment, such as working under bright, bad or faint light or in cold, hot, wet, damp or draughty conditions, are more frequently reported by essential employees (15 percent and 29 percent) than by other employees (8 percent and 19 percent).

Tab. 2 Critical occupations with the lowest hourly wages

Occupations	Average hourly wage
Occupations in gardening	8.48
Drivers and operators of construction and transportation vehicles and equipment	10.09
Occupations in cleaning services	10.83
Technical occupations in railway, aircraft and ship operations	11.08
(Retail) sales occupations selling foodstuffs	12.41
Driver of vehicles in road traffic	12.86
Occupations in animal husbandry	13.34
Doctors' receptionists and assistants	13.35
Occupations in non-medical therapy and alternative medicine	13.44
Retail sales occupations (without product specialisation)	14.00

Notes: Results are weighted. Source: Working Time Survey 2019; own calculations

Given the great importance of critical jobs for the economy, first, the socio-demographic, job-related and structural determinants of critical jobs are assessed; second, the working conditions in those jobs are examined.

5.2 Determinants of working in a critical occupation

The probability of performing a critical job, presented in table 3, is determined on the basis of three estimations, into which the explanatory variables are added sequentially[6]. Model 1 contains socio-demographic and household characteristics, model 2 adds job-related factors, and model 3 includes structural determinants as well as occupational information. A comparison across models 1, 2 and 3 reveals that the inclusion of the additional variable blocks in models 2 and 3 reduces the explanatory power of the socio-demographic and household characteristics in some cases.

According to model 3, female employees have a 2.5 percentage-point higher probability of working in a critical job than males. While age does not have any explanatory power, East German workers are more often observed in critical jobs. The results indicate a higher probability of being employed in a critical job only for workers with a polytechnic degree and a lower probability for individuals without vocational training. Overall, household characteristics do not have significant explanatory power.

Tab. 3 Determinants of working in a critical job (logistic regressions)

	(1) Critical job (AME)	(2) Critical job (AME)	(3) Critical job (AME)
Gender (1 = female)	0.139***	0.085***	0.025*
	(0.012)	(0.013)	(0.011)
Age (in years)	-0.010*	-0.009	-0.004
	(0.005)	(0.005)	(0.004)
Squared age (in years)	0.000*	0.000	0.000
	(0.000)	(0.000)	(0.000)
Place of residence (1 = East Germany)	0.016*	0.017**	0.011*
	(0.006)	(0.006)	(0.005)
Highest professional degree (Ref.: University degree)			
Vocational degree	0.051***	-0.015	-0.016
	(0.014)	(0.019)	(0.016)
Technical school, master	0.033	0.024	0.013
	(0.018)	(0.021)	(0.017)
Polytechnic degree	0.031	0.011	0.030*
	(0.020)	(0.020)	(0.015)
Another degree	0.083	0.082	0.052
	(0.053)	(0.052)	(0.045)
No professional degree	0.043	-0.051	-0.084*
	(0.041)	(0.041)	(0.034)
Unknown	0.153	0.102	0.016
	(0.108)	(0.120)	(0.098)
Marital status (Ref.: Single)			
Married	0.013	0.001	0.000
	(0.017)	(0.016)	(0.013)
Civil union	0.066	0.072	-0.009
	(0.059)	(0.057)	(0.047)
Divorced/widowed	0.056**	0.053**	0.032*
	(0.021)	(0.020)	(0.016)
Unknown	0.083	0.128	0.000
	(0.187)	(0.169)	(0.133)

[6] Descriptive statistics on the explanatory variables are provided in appendix table A1.

	(1) Critical job (AME)	(2) Critical job (AME)	(3) Critical job (AME)
Children in the household (Ref: No children in the household)			
Child younger than 7 years in the household	0.009	0.003	-0.006
	(0.022)	(0.022)	(0.018)
Child aged 7 to 12 years in the household	0.051*	0.034	0.020
	(0.021)	(0.020)	(0.016)
Child aged 13 to 18 years in the household	0.033	0.024	0.012
	(0.020)	(0.020)	(0.016)
Tenure (in years)		0.001	0.001**
		(0.001)	(0.000)
Form of employment (Ref.: Full-time)			
Part-time		0.071***	0.013
		(0.015)	(0.012)
Marginal employment		0.031	-0.006
		(0.057)	(0.051)
Unknown		-0.214*	-0.228*
		(0.101)	(0.089)
Type of contract (1 = Permanent contract)			
Fixed-term contract		-0.009	-0.035
		(0.025)	(0.021)
Unknown		0.332***	0.188***
		(0.016)	(0.017)
Complexity of job (Ref.: Unskilled or semi-skilled activity)			
Specialist activity		-0.062*	0.107***
		(0.030)	(0.030)
Complex specialist activity		-0.225***	-0.040
		(0.032)	(0.032)
Highly complex activity		-0.234***	-0.062
		(0.033)	(0.032)
Additional jobs (Ref.: No additional job)			
One additional job		0.024	-0.011
		(0.023)	(0.018)
More than one additional job		-0.071	-0.037
		(0.058)	(0.050)
Size of company (Ref.: More than 500 employees)			
Fewer than 9 employees			0.033
			(0.020)
10-49 employees			0.056***
			(0.015)
50-499 employees			0.033**
			(0.012)
Unknown			0.038
			(0.043)
Work council (Ref.: Existent)			
Non-existent			-0.070***
			(0.012)
Unknown			-0.011
			(0.029)

	(1) Critical job (AME)	(2) Critical job (AME)	(3) Critical job (AME)
Occupational segments (Ref.: Manufacturing)			
Agriculture, forestry and gardening			0.147**
			(0.051)
Manufacturing engineering			0.074**
			(0.024)
Construction			0.280***
			(0.031)
Food and hospitality			0.258***
			(0.041)
Medical and non-medical health care			0.802***
			(0.022)
Social and cultural services			0.507***
			(0.027)
Retail and trade			0.433***
			(0.030)
Corporate management and organisation			-0.119***
			(0.020)
Business services			0.369***
			(0.026)
IT and natural science services			0.349***
			(0.030)
Security			0.859***
			(0.023)
Transport and logistics			0.806***
			(0.023)
Cleaning			0.842***
			(0.032)
Number of observations	7268	7268	7268
Pseudo R^2	0.021	0.070	0.360
AIC	9898.623	9432.083	6541.460
BIC	54.598	9631.929	6872.239
Wald test	206.198	609.253	1475.287
p-value	0.000	0.000	0.000
Correct classification	57.636	62.479	79.045
Log-pseudolikelihood	-98.419	-94.402	-64.273

Notes: Standard errors in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Source: Working Time Survey 2019; own calculations

Regarding job-related factors, it is evident that the probability of being an essential employee rises with increasing tenure. While the form of employment and the type of contract do not have any significant influence, the complexity of the job plays a role. In particular, employees who perform specialist activities work in critical jobs significantly more often than employees in unskilled or semi-skilled activities. For structural factors, it is found that critical jobs are performed more frequently in medium-sized companies with between 10 and 500 employees. By contrast, employees in companies that do not have a work council are less likely to engage in critical jobs. Relative to that in the occupational segment of "manufacturing", the highest probabilities of working in a critical job exist in the segments "security", "cleaning", "transport and logistics" as well as "medical and non-medical health care".

5.3 Working conditions in critical jobs

To identify risk factors in critical jobs, the following analyses examine wages, physical proximity to others at work, working time patterns and physical working conditions. Due to the different scaling of the dependent variables, various multiple regressions are carried out. The corresponding functional form – linear, binary logistic or multinomial logistic estimation – is indicated in the tables.

The first crucial dimension of working conditions is wages. We perform Mincerian regressions on logarithmically transformed hourly wages and control for socio-demographic, job-related and structural factors.[7] The central variable of interest, the dummy indicator for whether a job is critical or not, is significantly negative (table 4). This coefficient implies that essential employees earn 4.49 percent lower wages than non-essential employees.[8]

Tab. 4 Estimation of wages (OLS regression)

	Hourly wages (log) (Coef.)
Critical job (1 = yes)	-0.046***
	(0.009)
Socio-demographic characteristics	x
Job characteristics	x
Structural characteristics	x
Number of observations	7268
R^2	0.424
F-Test	153.91
p-value (F-Test)	0.000

Notes: The estimations also include the socio-demographic, job-related and structural characteristics (without occupational segments) that are presented in model 3 of table 3 as control variables.
Standard errors in parentheses; * p < 0.05, ** p < 0.01, *** p < 0.001.
Source: Working Time Survey 2019; own calculations

The second important dimension of working conditions during the COVID-19 pandemic is the degree of physical proximity to others at work (table 5). Employees in critical jobs have a 15.5 percentage-point higher probability of performing a physically proximate job than non-essential workers. They are, on the other hand, 10 percentage points less likely to have the opportunity to work from home.

Tab. 5 Estimation of physical proximity to others at work

	Logistic regression	Logistic regression
	Physical proximity (AME)	Home office work (AME)
Critical job (1 = yes)	0.155***	-0.100***
	(0.011)	(0.011)
Socio-demographic characteristics	x	x
Job characteristics	x	x
Structural characteristics	x	x

[7] The complete regression results for models 4 to 9 can be obtained from the authors upon request.

[8] Since the regression coefficients indicate log points, these can be transformed into percentages by using the formula $(e^{\beta}-1)*100$.

	Logistic regression	Logistic regression
	Physical proximity (AME)	Home office work (AME)
Number of observations	7268	7251
Pseudo R^2	0.058	0.175
AIC	9318.081	6226.049
BIC	9566.166	6474.049
Wald test	529.985	992.400
p-value	0.000	0.000
Correct classification	63.126	80.279
Log-pseudolikelihood	-92.393	-62.265

Notes: The estimations also include the socio-demographic, job-related and structural characteristics (without occupational segments) that are presented in model 3 of table 3 as control variables. Standard errors in parentheses; * p < 0.05, ** p < 0.01, *** p < 0.001.
Source: Working Time Survey 2019; own calculations

The third dimension of working conditions is working time patterns. Table 6 presents the results for the duration of work and atypical working hours. Thus, employees in critical jobs work overtime significantly more often. In addition, essential employees have a higher probability of working early or late shifts, rotating day shifts as well as shift and night work. With regard to weekend work, there are no differences in the probability of working on Saturdays. However, essential employees are more likely to work on Sundays.

Tab. 6 Estimation of working time patterns – Duration of work and atypical working hours

	Linear regression (OLS)	Multinomial logistic regression (Base outcome: Working hours usually between 07:00 and 19:00)			Multinomial logistic regression (Base outcome: No weekend work)	
	Weekly overtime (in hours)	Only early or late shift work	Shift work without night work	Shift work and night work	Work on Saturdays	Working on Saturdays and Sundays
	(Coef.)	(AME)	(AME)	(AME)	(AME)	(AME)
Critical job (1 = yes)	0.452*** (0.112)	0.018** (0.007)	0.039*** (0.006)	0.052*** (0.006)	0.008 (0.009)	0.143*** (0.010)
Socio-demographic characteristics	x	x	x	x	x	x
Job characteristics	x	x	x	x	x	x
Structural characteristics	x	x	x	x	x	x
Number of observations	7268	7214	7214	7214	6934	6934
R^2	0.081	-/-	-/-	-/-	-/-	-/-
F-Test	14.59	-/-	-/-	-/-	-/-	-/-
p-value (F-Test)	0.000	-/-	-/-	-/-	-/-	-/-
Pseudo R^2	-/-	0.212	0.212	0.212	0.131	0.131
AIC	-/-	8986.647	8986.647	8986.647	11994.67	11994.67

	Linear regression (OLS)	Multinomial logistic regression (Base outcome: Working hours usually between 07:00 and 19:00)			Multinomial logistic regression (Base outcome: No weekend work)	
	Weekly overtime (in hours)	Only early or late shift work	Shift work without night work	Shift work and night work	Work on Saturdays	Working on Saturdays and Sundays
	(Coef.)	(AME)	(AME)	(AME)	(AME)	(AME)
BIC	-/-	9998.563	9998.563	9998.563	12487.45	12487.45
Wald test	-/-	103.736	103.736	103.736	3296.19	3296.19
p-value	-/-	0.000	0.000	0.000	0.000	0.000
Correct classification	-/-	-/-	-/-	-/-	-/-	-/-
Log-pseudolikelihood	-/-	-4346.323	-4346.323	-4346.323	-5440.718	-5440.718

Notes: The estimations also include the socio-demographic, job-related and structural characteristics (without occupational segments) that are presented in model 3 of table 3 as control variables. Standard errors in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Source: Working Time Survey 2019; own calculations

Disadvantageous characteristics are also apparent when considering working time autonomy (table 7). Critical jobs are more likely to be associated with regular on-call or standby service. Furthermore, essential employees report being able to decide on their breaks by themselves comparatively less often. The expectations of superiors and colleagues that workers are accessible in their private lives are comparatively higher in critical jobs. Finally, essential employees have a lower probability of separating work and private life.

Tab. 7 Estimation of working time patterns – Working time autonomy

	Logistic regression	Logistic regression	Multinomial logistic regression (Base outcome: Not expected to be accessible in private life)		Logistic regression
	Regular on-call or standby service	Make own decisions about breaks	Partially expected to be accessible in private life	Expected to be accessible in private life	Separation of work and private life possible
	(AME)	(AME)	(AME)	(AME)	(AME)
Critical job (1 = yes)	0.089*** (0.008)	-0.048*** (0.011)	0.023** (0.009)	0.052*** (0.010)	-0.048*** (0.011)
Socio-demographic characteristics	x	x	x	x	x
Job characteristics	x	x	x	x	x
Structural characteristics	x	x	x	x	x
Number of observations	7240	7247	7263	7263	7266
Pseudo R^2	0.112	0.048	0.035	0.035	0.035
AIC	4225.155	9114.095	12949.552	12949.552	8390.366
BIC	4555.749	9451.624	13624.831	13624.831	8728.023
Wald test	455.947	422.209	440.50	440.50	295.342
p-value	0.000	0.000	0.000	0.000	0.000
Correct classification	90.180	65.793	-/-	-/-	72.392
Log-pseudolikelihood	-2064.577	-4508.047	-6376.771	-6376.771	-4146.182

The last dimension examined concerns physical working conditions. With regard to muscular and skeletal strain, critical jobs are performed in a standing position significantly more often but in a sitting position less frequently (table 8). Additionally, essential employees work comparatively more often in a kneeling or bending position or above their heads. They also have to lift and carry heavy loads more frequently.

Tab. 8 Estimation of physical working conditions – Muscular and skeletal strain

	Logistic regression Working in a standing position (AME)	Logistic regression Working in a sitting position (AME)	Logistic regression Kneeling, bending, or overhead work (AME)	Logistic regression Lifting and carrying heavy loads (AME)
Critical job (1 = yes)	0.152*** (0.011)	-0.091*** (0.010)	0.053*** (0.007)	0.077*** (0.008)
Socio-demographic characteristics	x	x	x	x
Job characteristics	x	x	x	x
Structural characteristics	x	x	x	x
Number of observations	7268	7268	7252	7268
Pseudo R^2	0.278	0.269	0.264	0.247
AIC	7257.942	6839.500	3799.784	4413.909
BIC	7595.612	7177.170	4130.458	4751.579
Wald test	1471.433	1303.324	716.845	846.914
p-value	0.000	0.000	0.000	0.000
Correct classification	77.449	77.958	89.313	86.599
Log-pseudolikelihood	-3579.971	-3370.749	-1851.892	-2157.954

Notes: The estimations also include the socio-demographic, job-related and structural characteristics (without occu-pational segments) that are presented in model 3 of table 3 as control variables. Standard errors in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Source: Working Time Survey 2019; own calculations

Concerning strain from the working environment, essential employees report significantly more often that they do their job in noisy conditions; in bright, bad or faint light; and in cold, hot, wet, damp or draughty conditions (table 9). By contrast, they can less frequently influence the work tasks that must be carried out.

Tab. 9 Estimation of physical working conditions – Strain from the working environment

	Logistic regression Noise (AME)	Logistic regression Bright, bad, or faint light (AME)	Logistic regression Cold, heat, wetness, dampness, or draughts (AME)	Logistic regression Can influence the work tasks that must be carried out (AME)
Critical job (1 = yes)	0.056*** (0.010)	0.031*** (0.007)	0.050*** (0.009)	-0.024* (0.012)
Socio-demographic characteristics	x	x	x	x
Job characteristics	x	x	x	x
Structural characteristics	x	x	x	x
Number of observations	7261	7268	7252	7246
Pseudo R^2	0.187	0.097	0.217	0.047

	Logistic regression	Logistic regression	Logistic regression	Logistic regression
	Noise	Bright, bad, or faint light	Cold, heat, wetness, dampness, or draughts	Can influence the work tasks that must be carried out
	(AME)	(AME)	(AME)	(AME)
AIC	6303.349	3911.703	5172.305	9273.575
BIC	6634.082	4249.374	5502.979	9611.097
Wald test	1019.266	350.464	997.295	410.880
p-value	0.000	0.000	0.000	0.000
Correct classification	80.719	91.511	85.259	64.436
Log-pseudolikelihood	-3103.674	-1906.851	-2538.153	-4587.787

Notes: The estimations also include socio-demographic, job-related and structural characteristics (without occupa-tional segments) that are presented in model 3 of table 3 as control variables. Standard errors in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Source: Working Time Survey 2019; own calculations

5.4 Robustness checks

To check the robustness of our results regarding the categorisation of critical jobs, we re-estimated the determinants of critical occupations and their working conditions by using the alternative five-digit level classification of "systemically relevant occupations for supply and care" compiled by Burstedde et al. (2020) and the three-digit level classification of first-hour occupations from Koebe et al. (2020), which focuses more narrowly on frontline work. Basic descriptive results reveal marked differences. While our classification identifies 48.5 percent of jobs as critical, the figure is considerably greater (55.2 percent) when using the alternative five-digit level classification of Burstedde et al. (2020) and smaller (41.3 percent) when using the three-digit classification of Koebe et al. (2020). This indicates that on the one hand, we identified more than just frontline workers and that on the other hand, our 5-digit level occupations are more differen-tiated than those of Burstedde et al. (2020).

The robustness tests for the determinants of working in a critical job also show differences associated with the use of a broader or narrower definition of critical labour (table A2 in the appendix). The broader classification of Burstedde et al. (2020) does not indicate differences regarding gender, while the effect of specialist activities becomes insignificant. The narrower frontline work categorisation of Koebe et al. (2020) is characterised more significantly by female and part-time employment as well as by younger workers.[9] The robustness checks on working conditions in crit-ical jobs (table A3 in the appendix) consistently confirm our findings – with two exceptions, which are the expectation of superiors and colleagues that workers are accessible in their private lives and the opportunity to influence the work tasks that must be carried out – when the classification of Burstedde et al. (2020) is used. Estimates based on the classification of Koebe et al. (2020) differ from our main results and become insignificant regarding the duration of work, the separation of work and private life as well as physical strains from the working environment.

Overall, the robustness checks for the determinants of working in a critical job indicate that the characteristics of critical workers depend on the group definition used. However, essential workers are more likely to be female, to have a polytechnic degree, to have longer tenure, to work in specialist activities and to work in companies that have a works council. Across all robustness tests, disadvantages in terms of wages and higher physical proximity to others are evident in critical jobs. There are also more atypical working hours and less working time autonomy. Muscular, skeletal, and environmental strains exist with regard to working positions, carrying heavy loads and noise levels.

[9] Since this classification is based on three-digit occupations, occupational segments could not be included in the estimation due to multicollinearity.

6 Discussion of results

The COVID-19 pandemic has had a strong impact on various dimensions of social inequality in the labour market and on work-related strain. This seems to be particularly the case for employees in systemically relevant occupations (Blau et al. 2020; Lübker and Zucco 2020; Koebe et al. 2020) who ensure the maintenance of critical infrastructure as well as the provision of medical care and nursing services or the supply of essential goods. Such employees were asked by political actors and the general public to continue working despite the health risks arising from the pandemic (BMAS 2020; CISA 2020; CPNI 2021). These special circumstances increased the public's awareness of essential occupational groups and raised the question of the conditions under which essential employees work. However, only three quantitative analyses have been available to date (Blau et al. 2020; Lübker and Zucco 2020; Koebe et al. 2020), which provide inconsistent results regarding working conditions in critical jobs due to data restrictions and the analyses' mainly descriptive character. Against this backdrop, this study performed a more comprehensive analysis of working conditions in critical jobs. We were able to expand the previous research in three ways.

First, regarding data and methods, we used the representative German Working Time Survey 2019 to conduct our empirical analyses. These data allowed us both to determine critical jobs and to examine four dimensions of working conditions. Data was collected before the COVID-19 pandemic hit Germany, which ensures that the comparison groups as well as the variables of interest were unaffected by the pandemic. Furthermore, jobs could be classified at the 5-digit occupational classification level, which made differentiated categorisation with respect to systemic relevance possible. Beyond the descriptive evaluations that have been predominantly performed to date, our rich dataset allowed us to identify working conditions through multiple estimations, controlling for a variety of socio-demographic, job-related and structural factors.

Second, in terms of content, our descriptive findings indicated that 48.5 percent of employees worked in a critical job. Our multiple regressions revealed – in accordance with the findings of Blau et al. (2020) and Koebe et al. (2020) – that women in particular work in critical jobs. This also applies to employees holding a polytechnic degree, those with longer job tenure and those engaged in specialist activities. Critical jobs were more often located in medium-sized companies and in companies that had a work council. Furthermore, critical jobs could be found in the "security", "cleaning", "transport and logistics" as well as "medical and non-medical health care" sectors, a finding which is in line with those of Blau et al. (2020) and Koebe et al. (2020).

Third, regarding working conditions, our descriptive analyses showed that essential employees earned on average 18.75 euros per hour (gross) and thus 1.54 euros less than other employees. Among the lowest paid critical occupations were those in cleaning services, (retail) sales occupations selling foodstuffs and doctors' receptionists and assistants. The multiple estimates confirmed our descriptive findings, as well as the previous findings of Blau et al. (2020) and Koebe et al. (2020), that essential workers receive lower wages. Furthermore, essential employees were 15.5 percentage points more likely to work in jobs requiring physical proximity to others, while home office work could be done significantly less often. Both findings are in accordance with recent research on the correlation between critical work and physical proximity (Avdiu and Nayyar 2020; Dingel and Neiman 2020). Concerning working time patterns, critical jobs were associated with overtime work and atypical working hours (day and night shifts, Sunday work) significantly more often but involved a lesser degree of working time autonomy due to being regularly on call or on standby, facing higher expectations for accessibility in private life, making fewer decisions about breaks and being unable to separate work and private life. With regard to physical working conditions, our estimates indicated greater muscular and skeletal strain in critical jobs because of working more frequently in a standing, kneeling or bending position or in overhead activities and because of the requirement to lift and carry heavy loads. Finally, we revealed greater strain from the working environment (noisy conditions; bright, bad or faint light; cold, hot, wet, damp or draughty conditions; and the inability to influence one's work tasks) in critical jobs.

Fourth, research on systemically relevant occupations was theoretically embedded with approaches to human resource management that explain labour market segmentation (Hendry 2003; Osterman 2011; Kaufman 2013). According to these approaches, employees occupy unfavourable positions in the labour market, particularly when they have little power to act, which can be explained by access to resources such as professi-

onal knowledge and skills or by the specificity of their learned profession, by legal regulations, by collective agreements, and by internal institutions such as work councils (ibid.). While we did not discover educational differences between essential and non-essential employees – the former even had longer work tenures and worked in specialist activities more often – higher probabilities of working in critical jobs were observed among women, who have also been found to occupy inferior positions in the employment system in other research (Lucifora and Salverda 2009; Howell and Kalleberg 2019). Furthermore, essential employees reported a comparatively higher incidence of work councils. Thus, the socio-demographic and structural determinants did not reflect – except for the distribution of female workers – the crucial characteristics of employment in unfavourable labour market positions. However, a closer look at the occupational segments indicates that critical jobs are often located in sectors with little or no collective bargaining coverage, such as security, cleaning, transport and logistics as well as retail and trade (Ellguth and Kohaut (2019)). Finally, our findings on working conditions are in accordance with research on segmented labour markets (Kalleberg 2011; Osterman 2011; Kaufman 2013). In fact, the risks of significantly lower wages, higher physical proximity to others at work, comparatively longer working hours, more atypical working hours, less working time autonomy as well as greater muscular and skeletal strain and strain from the working environment tend to accumulate in critical jobs.

7 Conclusions

The COVID-19 pandemic has focused public attention on occupational groups that are highly important to the functioning of social life. Our empirical analyses highlighted that risks resulting from working conditions in critical jobs do not occur separately but cumulatively, which leads to severe health risks, as the cited literature has revealed. This accumulation of risks was already true before the pandemic. However, these unfavourable working conditions were exacerbated by the fact that the pandemic has aggravated existing strains.

A possible beneficial federal measure would be to define the group of critical jobs more precisely. As our robustness checks showed, the related socio-demographic, job-related and structural characteristics changed according to the definition of critical jobs used. A formal list based on common industry codes or occupational classifications could be used to better prioritise safety measures, protective equipment and other targeted benefits.

A further and already well-known public policy implication is related to occupational wage inequality. Our findings indicated that critical jobs are predominantly low-paid occupations in sectors with low collective bargaining coverage. Therefore, a longer-term measure would be to increase collective bargaining coverage in these sectors of the economy in order to raise the attractiveness of critical jobs. Because simply showing up to work has put many essential workers at risk, the high physical proximity to others and the associated risk of infection make it necessary to provide frequent COVID-19 tests, to cover hospitalisation and health costs.

Work-related strains from long and atypical working hours as well as physically demanding work increased during the COVID-19 pandemic since the labour of essential employees was required on a larger scale and with greater intensity than before. Physical stress could be reduced by allowing regular rest breaks during the working day. The health risks associated with long and atypical working hours could be reduced by adhering to daily maximum working hours and maintaining recovery phases between shifts in critical jobs. Such a balance of service provision and staff safety is all the more necessary to prevent burnout and insomnia during the times of increased workload caused by the COVID-19 pandemic. The work-related disadvantages and strains of close physical proximity to others, heavy physical demands and inconvenient working time patterns need to be addressed as a whole through different measures, as physical exhaustion often leads to individual failures to comply with occupational health and safety measures and in order to maintain the working capacity of this highly strained group of employees.

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Appendix

Tab. A1 Descriptive statistics for explanatory variables

	Mean	Standard deviation	Minimum	Maximum
Gender (1 = female)	0.47	0.499	0	1
Age (in years)	42.41	11.967	19	78
Squared age (in years)	1942.07	1030.629	361	6084
Place of residence (1 = East Germany)	0.19	0.389	0	1
Highest professional degree				
No professional degree	0.04	0.196	0	1
Vocational degree	0.57	0.495	0	1
Technical school, master	0.13	0.341	0	1
Polytechnic degree	0.07	0.250	0	1
University degree	0.18	0.384	0	1
Another degree	0.01	0.098	0	1
Unknown	0.01	0.076	0	1
Marital status				
Single	0.38	0.486	0	1
Married	0.50	0.500	0	1
Civil union	0.01	0.120	0	1
Divorced/widowed	0.10	0.306	0	1
Unknown	0.00	0.020	0	1
Children in the household				
No children in the household	0.67	0.469	0	1
Child younger than 7 years in the household	0.13	0.338	0	1
Child aged 7 to 12 years in the household	0.11	0.317	0	1
Child aged 13 to 18 years in the household	0.08	0.275	0	1
Tenure (in years)	11.31	10.748	0	51
Form of employment				
Full-time	0.75	0.435	0	1
Part-time	0.24	0.426	0	1
Marginal employment	0.01	0.121	0	1
Unknown	0.00	0.060	0	1
Type of contract				
Permanent contract	0.90	0.294	0	1
Fixed-term contract	0.10	0.294	0	1
Unknown	0.05	0.222	0	1
Complexity of job				
Unskilled or semi-skilled activity	0.06	0.243	0	1
Specialist activity	0.57	0.495	0	1
Complex specialist activity	0.19	0.395	0	1
Highly complex activity	0.17	0.378	0	1

	Mean	Standard deviation	Minimum	Maximum
Additional jobs				
No additional job	0.91	0.285	0	1
One additional job	0.08	0.273	0	1
More than one additional job	0.01	0.089	0	1
Size of company				
Fewer than 9 employees	0.10	0.306	0	1
10-49 employees	0.24	0.428	0	1
50-499 employees	0.37	0.482	0	1
More than 500 employees	0.27	0.445	0	1
Unknown	0.02	0.127	0	1
Work council				
Existent	0.59	0.492	0	1
Non-existent	0.36	0.481	0	1
Unknown	0.05	0.215	0	1
Occupational segments				
Agriculture, forestry and gardening	0.02	0.130	0	1
Manufacturing	0.07	0.251	0	1
Manufacturing engineering	0.13	0.340	0	1
Construction	0.07	0.252	0	1
Food and hospitality	0.04	0.199	0	1
Medical and non-medical health care	0.11	0.316	0	1
Social and cultural services	0.11	0.307	0	1
Retail and trade	0.08	0.267	0	1
Corporate management and organisation	0.08	0.277	0	1
Business services	0.12	0.327	0	1
IT and natural science services	0.05	0.211	0	1
Security	0.03	0.160	0	1
Transport and logistics	0.09	0.281	0	1
Cleaning	0.01	0.109	0	1
Number of observations	7268			

Notes: Results are weighted.
Source: Working Time Survey 2019; own calculations

Tab. A2 Robustness checks of the determinants of working in a critical job (logistic regressions)

	Critical job Specification from model 3 of table 3 (AME)	Critical job Five-digit level classification of Burstedde et al. (2020) (AME)	Critical job Three-digit level classification of Koebe et al. (2020) (AME)
Gender (1 = female)	0.025*	0.012	0.127***
	(0.011)	(0.012)	(0.013)
Age (in years)	-0.004	-0.000	-0.009*
	(0.004)	(0.004)	(0.005)
Squared age (in years)	0.000	-0.000	0.000*
	(0.000)	(0.000)	(0.000)
Place of residence (1 = East Germany)	0.011*	0.012*	0.001
	(0.005)	(0.005)	(0.006)
Highest professional degree (Ref.: University degree)			
Vocational degree	-0.016	-0.003	0.026
	(0.016)	(0.017)	(0.019)
Technical school, master	0.013	0.022	0.051*
	(0.017)	(0.019)	(0.021)
Polytechnic degree	0.030*	0.050**	0.146***
	(0.015)	(0.017)	(0.020)
Another degree	0.052	0.090	0.118*
	(0.045)	(0.049)	(0.052)
No professional degree	-0.084*	-0.051	-0.012
	(0.034)	(0.040)	(0.041)
Unknown	0.016	-0.019	0.309**
	(0.098)	(0.082)	(0.107)
Marital status (Ref.: Single)			
Married	0.000	-0.004	-0.003
	(0.013)	(0.014)	(0.016)
Civil union	-0.009	-0.027	0.081
	(0.047)	(0.052)	(0.056)
Divorced/widowed	0.032*	0.030	0.037
	(0.016)	(0.018)	(0.020)
Unknown	0.000	0.242*	0.138
	(0.133)	(0.115)	(0.136)
Children in the household (Ref: No children in the household)			
Child younger than 7 years in the household	-0.006	-0.013	-0.001
	(0.018)	(0.019)	(0.022)
Child aged 7 to 12 years in the household	0.020	0.016	0.033
	(0.016)	(0.018)	(0.020)
Child aged 13 to 18 years in the household	0.012	0.012	0.019
	(0.016)	(0.017)	(0.019)
Tenure (in years)	0.001**	0.002**	0.001
	(0.000)	(0.001)	(0.001)

	Critical job Specification from model 3 of table 3 (AME)	Critical job Five-digit level classification of Burstedde et al. (2020) (AME)	Critical job Three-digit level classification of Koebe et al. (2020) (AME)
Form of employment (Ref.: Full-time)			
Part-time	0.013	0.019	0.100***
	(0.012)	(0.013)	(0.015)
Marginal employment	-0.006	-0.127*	0.064
	(0.051)	(0.051)	(0.054)
Unknown	-0.228*	-0.325***	-0.160
	(0.089)	(0.079)	(0.086)
Type of contract (1 = Permanent contract)			
Fixed-term contract	-0.035	-0.042	-0.006
	(0.021)	(0.022)	(0.025)
Unknown	0.188***	0.168***	0.068***
	(0.017)	(0.017)	(0.019)
Complexity of job (Ref.: Unskilled or semi-skilled activity)			
Specialist activity	0.107***	-0.018	0.072*
	(0.030)	(0.030)	(0.032)
Complex specialist activity	-0.040	-0.131***	-0.210***
	(0.032)	(0.032)	(0.033)
Highly complex activity	-0.062	-0.181***	-0.288***
	(0.032)	(0.032)	(0.035)
Additional jobs (Ref.: No additional job)			
One additional job	-0.011	-0.040	0.063**
	(0.018)	(0.020)	(0.022)
More than one additional job	-0.037	-0.067	0.054
	(0.050)	(0.052)	(0.057)
Size of company (Ref.: More than 500 employees)			
Fewer than 9 employees	0.033	-0.014	-0.005
	(0.020)	(0.022)	(0.024)
10-49 employees	0.056***	0.040*	0.001
	(0.015)	(0.016)	(0.017)
50-499 employees	0.033**	0.009	-0.045**
	(0.012)	(0.013)	(0.014)
Unknown	0.038	0.013	0.053
	(0.043)	(0.045)	(0.051)
Work council (Ref.: Existent)			
Non-existent	-0.070***	-0.076***	-0.094***
	(0.012)	(0.014)	(0.015)
Unknown	-0.011	0.017	-0.031
	(0.029)	(0.033)	(0.034)

	Critical job Specification from model 3 of table 3 (AME)	Critical job Five-digit level classification of Burstedde et al. (2020) (AME)	Critical job Three-digit level classification of Koebe et al. (2020) (AME)
Occupational segments (Ref.: Manufacturing)			
Agriculture, forestry and gardening	0.147**	0.106*	-/-
	(0.051)	(0.052)	-/-
Manufacturing engineering	0.074**	0.211***	-/-
	(0.024)	(0.027)	-/-
Construction	0.280***	0.231***	-/-
	(0.031)	(0.032)	-/-
Food and hospitality	0.258***	0.351***	-/-
	(0.041)	(0.043)	-/-
Medical and non-medical health care	0.802***	0.744***	-/-
	(0.022)	(0.024)	-/-
Social and cultural services	0.507***	0.465***	-/-
	(0.027)	(0.028)	-/-
Retail and trade	0.433***	0.344***	-/-
	(0.030)	(0.032)	-/-
Corporate management and organisation	-0.119***	-0.066**	-/-
	(0.020)	(0.025)	-/-
Business services	0.369***	0.346***	-/-
	(0.026)	(0.027)	-/-
IT and natural science services	0.349***	0.583***	-/-
	(0.030)	(0.028)	-/-
Security	0.859***	0.585***	-/-
	(0.023)	(0.043)	-/-
Transport and logistics	0.806***	0.796***	-/-
	(0.023)	(0.023)	-/-
Cleaning	0.842***	0.801***	-/-
	(0.032)	(0.034)	-/-
Number of observations	7268	7268	7268
Pseudo R^2	0.360	0.083	0.042
AIC	6541.460	9149.123	9638.870
BIC	6872.239	9390.317	9838.716
Wald test	1475.287	694.476	386.339
p-value	0.000	0.000	0.000
Correct classification	79.045	66.703	59.494
Log-pseudolikelihood	-64.273	-90.3849	-96.4105

Notes: Standard errors in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Source: Working Time Survey 2019; own calculations

Tab. A3 Robustness checks for working conditions in critical jobs

		Explanatory variable: Critical job (1=yes)		
	Dependent variables	Results from our specification in tables 4-9	Robustness check: Five-digit level classification of Burstedde et al. (2020)	Robustness check: Three-digit level classification of Koebe et al. (2020)
Wages	Hourly wages (log) (Coef.)	-0.046***	-0.021*	-0.024*
		(0.009)	(0.009)	(0.009)
Physical proximity to others at work	Physical proximity (AME)	0.155***	0.132***	0.204***
		(0.011)	(0.011)	(0.011)
	Home office work (AME)	-0.100***	-0.062***	-0.070***
		(0.011)	(0.009)	(0.010)
Duration of work and atypical work hours	Weekly overtime (in hours) (Coef.)	0.452***	0.493***	-0.140
		(0.112)	(0.109)	(0.111)
	Only early or late shift work (AME)	0.018**	0.024***	0.013
		(0.007)	(0.007)	(0.007)
	Shift work without night work (AME)	0.039***	0.025***	0.031***
		(0.006)	(0.006)	(0.006)
	Shift work and night work (AME)	0.052***	0.034***	0.043***
		(0.006)	(0.006)	(0.006)
	Working on Saturdays (AME)	0.008	0.005	-0.004
		(0.009)	(0.009)	(0.009)
	Working on Saturdays and Sundays (AME)	0.143***	0.115***	0.071***
		(0.010)	(0.010)	(0.010)
Working time autonomy	Regular on-call or standby service (AME)	0.089***	0.086***	0.062***
		(0.008)	(0.008)	(0.007)
	Make own decisions about breaks (AME)	-0.048***	-0.032**	-0.047***
		(0.011)	(0.011)	(0.012)
	Partially expected to be accessible in private life (AME)	0.023**	0.010	-0.000
		(0.009)	(0.008)	(0.009)
	Expected to be accessible in private life (AME)	0.052***	0.040***	0.016
		(0.010)	(0.010)	(0.010)
	Separation of work and private life possible (AME)	-0.048***	-0.036***	-0.020
		(0.011)	(0.011)	(0.011)

		Explanatory variable: Critical job (1=yes)		
	Dependent variables	Results from our specification in tables 4-9	Robustness check: Five-digit level classification of Burstedde et al. (2020)	Robustness check: Three-digit level classification of Koebe et al. (2020)
Muscular and skeletal strain	Working in a standing position	0.152***	0.109***	-0.005
		(0.011)	(0.011)	(0.012)
	Working in a sitting position	-0.091***	-0.068***	0.035**
		(0.010)	(0.010)	(0.011)
	Kneeling, bending, or overhead work	0.053***	0.050***	0.021**
		(0.007)	(0.007)	(0.007)
	Lifting and carrying heavy loads	0.077***	0.061***	0.045***
		(0.008)	(0.008)	(0.008)
	Noise	0.056***	0.045***	-0.054***
		(0.010)	(0.010)	(0.010)
	Bright, bad, or faint light	0.031***	0.027***	0.013
		(0.007)	(0.007)	(0.007)
	Cold, heat, wetness, dampness, or draughts	0.050***	0.043***	0.013
		(0.009)	(0.009)	(0.009)
	Can influence the work tasks that must be carried out	-0.024*	-0.013	0.003
		(0.012)	(0.011)	(0.012)

Notes: The estimations also include the socio-demographic, job-related and structural characteristics (without occupational segments) that are presented in model 3 of table 3 as control variables. Standard errors in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Source: Working Time Survey 2019; own calculations

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Federal Institute for Occupational Safety and Health (BAuA) | Friedrich-Henkel-Weg 1-25 | D 44149 Dortmund |
phone: +49 231 9071-2071 | *info-zentrum@baua.bund.de* | *www.baua.de* | Author: Matthias Dütsch |
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