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The COVID-19 pandemic and firms' E-learning use: implications for inequality in training opportunities

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Abstract

This paper investigates whether the adoption of E-learning by firms contributed to offset the decrease in firm-sponsored training during the COVID-19 pandemic. Using a novel firm level survey linked with administrative data on the universe of workers within those firms, I study the role of E-learning in firms' training activities during the crisis. I find that the COVID-19 pandemic substantially decreased firm-sponsored training by up to 11 percentage points. However, firms' ability to use E-learning nullifies this negative effect. Furthermore, the differential capabilities of firms to apply E-learning might exacerbate already prevalent inequalities in training opportunities.

Keywords Inequality in firm-financed training, Labor market inequality, COVID-19 pandemic

JEL Classification I240, L230, D230

1 Introduction

The COVID-19 pandemic provided a massive shock to German firms, as not even 6 months went by from the first reports on the virus to the lockdown during the first wave in March 2020. The crisis required governments to restrict contact between individuals as much as possible and thus, at times, cancel all social interactions not absolutely necessary, which led to far-reaching implications for social life but also widely affected the labor market by changing the mode of working together from face-to-face contact to the virtual realm.

As previous economic crises demonstrated, economic decline comes with reduced training activities (Cordes and Haaren 2015). The COVID-19 pandemic was likewise marked by a substantial decrease in training due to the economically constraining nature of the crisis (Jost and Leber 2021). However, the COVID-19 pandemic differs from previous economic crises by additionally impeding the conduct of training while restrictions on face-to-face contacts remained. This latter mechanism is unique to the COVID-19 pandemic and differs from the aforementioned economic mechanism, as even firms without economic restrictions might have been unable to conduct training activities. The feasibility of training measures thus depended not only on the economic situation of firms but also on the transferability of training measures to the virtual space. While the economic mechanism is known to affect the supply of firm-sponsored training from previous economic crises, the role of E-learning in firms' ability to maintain training during the crisis is rather unclear. In addition, the pandemic affected males and females differently, as the possibility to externalize care activities decreased, exposing especially females to the double burden of care and job responsibilities (Illing et al. 2022). This raises the question of demand-driven changes in training activities during the pandemic, as females might have been less able to participate in training compared to males due to increasing care responsibilities.

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Assessing the relationship between the COVID-19 pandemic and training, this article focuses on the most common form of training in Germany: firm-sponsored non-formal further training, i.e., comparatively short training courses that do not lead to a recognized educational degree (Ehlert 2017). I argue that the ability of firms to maintain training activities during the crisis hinged on both supply-side and demand-side factors. On the supply side, the economic situation during the pandemic and the ability of firms to effectively apply E-learning are important mechanisms mediating the effect of the pandemic on training. On the demand side of training, the gender of employees might have driven changes in firms' training activities, as especially female employees were confronted with additional care responsibilities. Therefore, I contribute to the literature on the pandemic by studying the relationship between the COVID-19 pandemic and firms' training activities, considering the supply- and demand-side within training regimes. I investigate whether firms' use of E-learning can mitigate the exogenous shock of the crisis on training. Additionally, I investigate the impact of the pandemic on training and whether the role of E-learning is gender-specific.

Based on the most recent wave of the IAB-ZEW-Labor Market 4.0-Establishment Survey (Hanebrink et al. 2021), I study the effect of the COVID-19 pandemic on firms training activities and the role of E-learning adaptation for this exogenous shock. Using fixed effects regressions at the firm level, I regress training shares within firms for the years 2019 and 2020 on a categorical variable for firms' economic situation during the COVID-19 pandemic and dummies indicating firms' ability to use E-learning and gender shares. I link the establishment-level survey data with administrative data providing firm characteristics (bhp_7520_m06_v1) and the universe of workers within those firms (IAB Employment History v10.07.00-202112). To measure firms' access to E-learning, I use a time-invariant variable on the importance of E-learning for firms' training activities measured based on firms' agreement with the following statement considering their training activities during the last 5 years: "We are increasingly using E-learning for training". As this item only informs on the importance of E-learning within firms but not on the actual E-learning take-up during the pandemic, I link the working from home (WFH) feasibility (Alipour et al. 2023) of workers and compute an establishment-level WFH feasibility. This allows to identify which firms are likely to be more able to efficiently apply E-learning to train their workforce.

Results show a substantial decline in firms' training activities of around 7 percentage points. While the economic situation of firms can explain part of this decline, even firms facing a positive product demand substantially reduce training. Only firms that could efficiently use E-learning maintained training activities during the pandemic. Further analyses provide evidence that the decline in firms' training activities is not only driven by supply-side factors (firms' economic situation and E-learning use) but also likely by demand-side factors: Firms with predominantly female employees show more severe decreases in training activities, hinting at a double burden for women during the pandemic due to employment and care responsibilities. Moreover, these firms benefited more from the use of E-learning.

This study makes a three-fold contribution to the literature. First, it describes the relation between the COVID-19 pandemic and firms' training activities and investigates important heterogeneities alongside the economic situation of firms during the pandemic and their use of E-learning in a longitudinal research design. Second, building on a novel linked employer-employee dataset, the study provides evidence that there is substantial variation in the ability of firms to make use of E-learning and that this is consequential for the decline in training during the pandemic. Third, the study provides descriptive evidence resonating with the notion that the COVID-19 pandemic might have exacerbated existing inequalities in training participation.

2 Research on training and the COVID-19 pandemic

Previous economic crises demonstrated that the economic decline of firms is associated with a reduction in firm-sponsored training (Cordes and Haaren 2015). Economic decline and economic uncertainty require firms to cut costs. Decreasing firm-sponsored training activities is easily implemented for affected firms, as firms can reduce training activities immediately and without affecting their capacity to stay productive in the short run. Descriptive studies show that the COVID-19 pandemic was likewise marked by a substantial decrease in firms' training activities due to the economically constraining nature of the crisis (Jost and Leber 2021). Besides the economic situation, restrictions on face-to-face contact impeded training measures, requiring firms to remodel the conduct of training measures.

The restriction of face-to-face contact resulted in a huge rise in working from home (WFH) wherever possible with regard to the transferability of tasks and the availability of necessary infrastructure (Bick et al. 2023). This change in work mode also required a change in training mode from face-to-face training to conducting training in a digital format wherever possible. While technical barriers impeded the implementation of WFH, most employees who were able to work from home also made use of it (Frodermann et al. 2021). Hereby, there

is considerable variation across industries in the use of WFH, as WFH is more common in industries with better educated and better paid workers (Bartik et al. 2020). These changes in work mode were accompanied by the digital transformation of production processes (Kudyba 2020), especially targeted at enabling WFH (Bloom et al. 2021). The change to technology-intensive operational modes also promoted firm-sponsored training in firms (Gathmann et al. 2023).

While the relationship between the COVID-19 pandemic and WFH is well understood, few studies have investigated the determinants of the relationship between the COVID-19 pandemic and firms' training activities. Worldwide, the COVID-19 pandemic disrupted skill formation (International Labour Office 2021). In Germany, training in workplaces experienced a century low in 2020 (Jost and Leber 2021). Similar to access to WFH, the decline in training also shows substantial variation across industries and worker types, suggesting that disadvantaged and low-skilled workers especially missed out on training opportunities (Paciorek et al. 2021). The decline of training activities during the COVID-19 pandemic in Germany amounts to around 30 percent (Flake et al. 2021), considering all types of vocational training, to 60 percent (Jost and Leber 2021), considering training in workplaces. At the firm-level, the necessity to restrict face-to-face contact during the crisis is the primary reason to cancel training activities, leading to a third of firms using E-learning for the first time in the COVID-19 pandemic and over 40 percent of firms expanding their use of E-learning (Bellmann et al. 2020). This resonates with studies on individual level, finding an expansion of E-learning, especially for higher-qualified workers during the COVID-19 pandemic (Kleinert et al. 2021).

The aforementioned studies point out mechanisms for the supply side of firm-sponsored training. Firms experiencing economic uncertainty and less access to E-learning should show stronger decreases in training. However, the pandemic also affected the demand side of training, e.g., by exposing individuals to increasing care responsibilities. Based on digital trace data, a US. study finds that the majority of child care centers closed throughout the pandemic, many even over prolonged periods (Lee and Parolin 2021). In Germany, closures of schools and child care facilities likewise led to additional burdens, especially for mothers providing extra child care during the pandemic (Illing et al. 2022). While longitudinal studies observe a short and small shift to a more egalitarian division of care work within couples, this diffusion of care work is driven by couples where mothers experience a high employment intensity and are unable to work from home (Boll et al. 2023). This gender biased increase in care responsibilities resulted in a reduction in working hours most pronounced for mothers with young children (Collins et al. 2021). This additional burden and the resulting decrease in working hours for females might also translate to a deterioration in training participation.

Training can support firms during the pandemic by ensuring that workers remain productive throughout changes in workplace location, technology use, and work organization (Gathmann et al. 2023). However, there are few studies that have investigated the participation of workers in training during the crisis by considering the role of E-learning in enabling firms to maintain training activities. Training is known to yield positive monetary returns (Konings and Vanormelingen 2015) and increase career stability (Dieckhoff 2007). However, workers with higher skills or educational attainment are far more likely to access training sponsored by their firms (O'Connell and Byrne 2012), making the role of the COVID-19 pandemic for firms' training activities a pressing topic. A recent study provides evidence that the COVID-19 pandemic might indeed have changed inequalities in the participation in training (Kleinert and Zoch 2023). I contribute to this literature on the effect of the COVID-19 pandemic on training by studying supply- and demand-side factors affecting firms training activities. Furthermore, this study provides descriptive evidence on the relationship between the effect of the COVID-19 pandemic on training and inequality in training opportunities.

3 The COVID-19 pandemic and firms' training activities

The COVID-19 pandemic affected both the supply- and demand-side of training. On the demand-side, this article focuses on two mechanisms. The first mechanism is the deterioration of the economic situation and the increasing economic uncertainty of firms. Previous economic crises showed that the economic situation of firms is an important determinant of training activities. Firms that experience economic decline and economic uncertainty during a crisis can reduce training activities to save costs. Therefore, firms' training activities should decrease more if their economic situation is impacted more severely by the pandemic:

> *H1 Decreases in the demand for firms' products and services during the COVID-19 pandemic are associated with stronger decreases in firms' training activities.*

The second mechanism on the supply-side of training is the ability of firms to apply E-learning to maintain training activities. The COVID-19 pandemic necessitated the reduction of face-to-face contact, requiring the use of E-learning to shift training to the virtual space. Therefore,

firms using E-learning are at an advantage in the course of the pandemic in terms of training activities:

H2 Firms with a high ability to use E-learning for training show smaller decreases in training activities during the COVID-19 pandemic.

On the demand-side, the pandemic led to the closure of child care facilities, resulting in a gender biased care burden, especially at the expense of women. Irrespective of access to E-learning, workplaces with a high share of female employees might have been less able to maintain training due to the additional burden of employees with care responsibilities:

H3 Firms with predominantly female employees show more pronounced decreases in training activities during the COVID-19 pandemic.

The role of E-learning in the gender-specific effects of the pandemic on training is a priori unclear. E-learning might have provided training opportunities to employees with additional care responsibilities, as E-learning offers more flexibility to participants with respect to time and space. However, the additional care responsibilities as well as the reduction of working hours of employees with care responsibilities might counteract this positive effect. Therefore, while still investigating the role of E-learning for firms with predominantly female employees, this article does not formulate a directed hypothesis on this relationship.

4 Data, measures, and statistical models

4.1 Data

To study the effect of the COVID-19 pandemic on firms' training activities, this article uses the second wave of the IAB-ZEW-Labor Market 4.0-Establishment Survey (Hanebrink et al. 2021). The first wave of the survey was collected in 2016, and the second wave was collected between August 2021 and June 2022. This dataset is a representative employer survey on the use of digitization and automation technologies in German establishments,[1] including both manufacturers and service providers. The survey also includes information about firms' training activities in the years 2016, 2019, and 2020 surveyed retrospectively. Firm-sponsored non-formal further training best describes the training activities recorded within the survey, i.e., comparatively short training courses that do not lead to a recognized educational degree. The survey also provides a self-assessment of the economic situation during the COVID-19 pandemic and the importance of E-learning for conducting training. The firm survey is a random sample of all German establishments registered at the German Federal Employment Agency, stratified by sector, establishment size, and location.

I link this survey dataset to the Establishment History Panel (BHP; Ganzer et al. 2021), which provides yearly information on all establishments with at least one employee liable to social security or at least one marginal part-time employee on June 30th. The BHP contains establishment information about industry, location, numbers, and wages of employees by various characteristics, employee flows, and foundation and closure dates, allowing for controlling various establishment-level variables.

Furthermore, I link the universe of employees of the establishments included in the survey using the social security records Integrated Employment Biographies (IEB V16.01.00-202112) provided by the Institute for Employment Research (IAB). The dataset includes information on all German employees liable to social security contributions, benefit recipients, unemployed searching for employment, and participants in active labor market policy measures, thus excluding self-employed, civil servants, and students. Based on the occupational codes of employees provided in the IEB data, I link a measure on the WFH feasibility of occupations given by Alipour et al. (2023) to be able to identify which firms can efficiently apply E-learning. To assess the feasibility of WFH in occupations, the study by Alipour et al. (2023) asked employees whether WFH is generally possible in their workplace. After the linkage of these data sources, I end up with an analysis sample of 1555 firms and 3110 firm-years for the multivariate analyses focusing on the years 2019 and 2020.

4.2 Measures

To measure firms' access to E-learning, I use a time-invariant variable on the importance of E-learning for firms training activities. Figure 1 shows the agreement with the following statement considering firms' training activities during the last 5 years: "We are increasingly using E-learning for training". While this does not provide the level of E-learning use, it serves as a proxy variable for actual E-learning use.

Comparing the responses from the first wave of BIZA in 2016 (gray bars) to the responses from the second wave of BIZA in 2021/22 (black bars), we clearly find that firms shifted to E-learning. This shift to E-learning between the pre-COVID wave and the second wave in 2021/22 is in line with other survey evidence, finding an E-learning uptake during the pandemic (Bellmann et al. 2020). In 2021/22, only around a third of firms strongly disagreed, disagreed, or neither disagreed nor agreed with the statement that the use of E-learning for training

[1] Throughout the text, I use establishment and firm interchangeably. The level of measurement in the datasets is at the workplace. This is not always equal to the firm level, as firms can consist of multiple establishments.

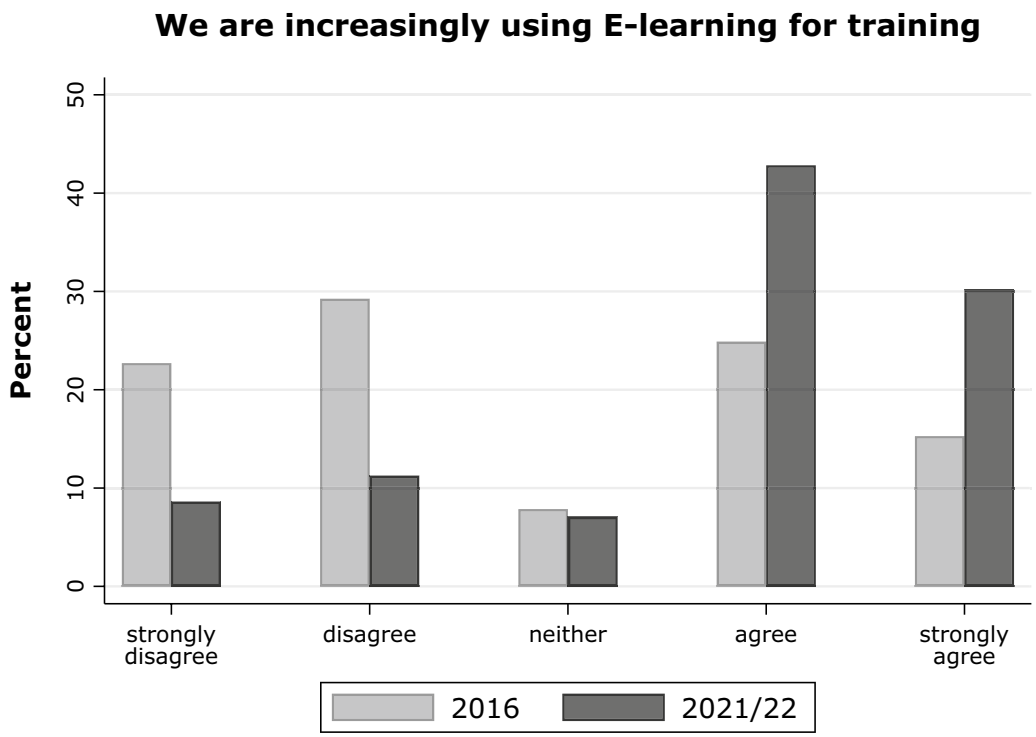

Fig. 1 Self-assessment of firms' E-learning use in 2016 and 2021/22. Data are weighted with cross-sectional weights. The bars show the responses to the survey item on the importance of E-learning as a measure to conduct training. The gray bars show the responses from the first wave of the survey in 2016 for firms that participated in the first and second waves of the survey. The black bars show the responses of the second wave of the survey in 2021/22 for firms that participated in the second wave of the survey. *Source:* Own calculations using the second wave of IAB-ZEW-Labor Market 4.0-Establishment Survey

has increased for their training activities during the last 5 years. Around 40 percent of firms agreed with the statement, and around 30 percent strongly agreed. I use firms that strongly agreed to the statement in the survey of 2021/22 (rightmost black bar) to identify firms where E-learning is an important measure for firms to conduct training activities.

The E-learning variable allows to identify firms where the use of E-learning is important but does not provide the share of training measures that are conducted via E-learning. To identify firms where E-learning is plausibly able to cover the majority of training measures, I use an index on the feasibility of WFH considering the occupational composition of a firm in 2019. Firms with an occupational structure allowing them to implement WFH are also able to use E-learning more efficiently to conduct training activities. I use a measure by Alipour et al. (2023) that is based on items of the 2018 BIBB/BAuA survey asking workers whether WFH is possible in their job (see bottom section of Table S-1 for the underlying survey items). WFH feasibility thus captures whether it is technologically feasible to perform a job at least partly from home. Using the occupational codes of the universe of workers within the surveyed firms, I aggregate the WFH feasibility at the firm level. Based on the sample mean of the WFH measure in 2019, I construct a time-invariant indicator for firms with low and high WFH feasibility. I combine this WFH measure with the E-learning measure, categorizing firms as E-learners if they have high WFH feasibility and strongly agree with E-learning being important. This allows me to study firms that can be expected to efficiently use E-learning to maintain training activities during the COVID-19 pandemic: those with increasing use of E-learning and high WFH feasibility for the majority of the firm's employees.

As a further important supply-side determinant of training during the COVID-19 pandemic, I use the economic situation of firms during the crisis. I measure this based on a survey question, whether the demand for products or services the firms offer decreased, remained unchanged, or increased during the COVID-19 pandemic. Table 1 shows a cross-tabulation of the E-learning measure and changes in product demand during the pandemic. 9.88 percent of firms facing decreasing demand, 12.71 percent of firms facing unchanged demand, and 18.07 percent facing increasing demand for the products or services they offer are in the E-learning group. Table

Table 1 E-learning use by changes in product demand during the COVID-19 pandemic

Demand change	Comparison %	E-learner %	Total
Decrease	90.12	9.88	392
Unchanged	87.29	12.71	577
Increase	81.93	18.07	586
Total	1116	439	1555

Data are weighted with cross-sectional weights. Column 1 provides the shares of firms where E-learning is not important for training and that have faced decreasing (row 1), unchanged demand (row 2), and increasing demand (row 3) for the services and products they offer since the COVID-19 pandemic began. The E-learner group are firms that strongly agreed with the statement that they increasingly use E-learning for training and have a high feasibility of WFH

Source: Own calculations using the second wave of IAB-ZEW-Labor Market 4.0-Establishment Survey

S-1 in the appendix provides an extensive description of all the underlying survey items.

To measure the role of demand-side mechanisms, I consider the role of gender composition within workplaces. Based on firms' female share in 2019, I construct a time-invariant indicator for firms with low and high female shares. This allows me to study firms with predominantly female employees (more than 50 percent female employees).

4.3 Analytical strategy

To identify the effect of E-learning on firms' training activities, I use an analytical strategy given by the following formulas:

Equation	Model
$Train_{it} = \beta_0 + \beta_1 Covid_t + X_{it} + \mu_i + \epsilon_{it}$	*M1: Raw COVID effect*
$Train_{it} = \beta_0 + \beta_1 Covid_t + \beta_2 (Covid_t * Demand_i) + X_{it} + \mu_i + \epsilon_{it}$	*M2: by demand*
$Train_{it} = \beta_0 + \beta_1 Covid_t + \beta_2 (Covid_t * EL_i) + X_{it} + \mu_i + \epsilon_{it}$	*M3: by EL*
$Train_{it} = \beta_0 + \beta_1 Covid_t + \beta_2 (Covid_t * Demand_i) + \beta_3 (Covid_t * EL_i) + \beta_4 (Covid_t * EL_i * Demand_i) + X_{it} + \mu_i + \epsilon_{it}$	*M4: by demand * EL*
$Train_{it} = \beta_0 + \beta_1 Covid_t + \beta_2 (Covid_t * low\ female\ share_i) + X_{it} + \mu_i + \epsilon_{it}$	*M5: by female share*
$Train_{it} = \beta_0 + \beta_1 Covid_t + \beta_2 (Covid_t * low\ female\ share_i) + \beta_3 (Covid_t * EL_i) + \beta_4 (Covid_t * EL_i * low\ female\ share_i) + X_{it} + \mu_i + \epsilon_{it}$	*M6: by EL * female share*

The dependent variable $Train_{it}$ denotes the share of trained workers in firm i at year t. $Covid_t$ has the value 0 for all firm-years in 2019 and switches to 1 in 2020. The coefficient β_1 in model M1 provides the change in the training share within firms between the years 2019 and 2020. Model M2 provides the change in training share between 2019 and 2020 due to firms' economic situation during the pandemic. $Demand_i$ is a time-invariant categorical variable indicating whether firms experienced decreasing, unchanged, or increasing demand for their services and products during the pandemic. The interaction term ($Covid_t \times Demand_i$) in model M2 tests hypothesis H2 on the role of the economic situation of firms. The coefficient β_2 in model M2 provides the difference in the change in training share for firms with unchanged or increasing demand in reference to firms with decreasing product demand. EL_i in model M3 is a dummy variable indicating firms' ability to use E-learning. The interaction term ($Covid_t \times EL_i$) in model M3 tests hypothesis H3 on the role of E-learning use. The coefficient β_2 in model M3 provides the difference in the change in training share comparing firms with low (reference) and high ability to use E-learning. The three-way interaction ($Covid_t \times EL_i \times Demand_i$) in model M4 provides the heterogeneous effect of the pandemic on firms training shares, both by E-learning and the economic situation of firms. The coefficient β_1 in model M4 provides the change in training for the reference group of firms with decreasing demand and low ability to use E-learning. The coefficients β_2, β_3, and β_4 in model M4 provide the difference to the reference group by the E-learning and demand characteristics of firms. The coefficient β_1 in model M5 provides the change in training for the reference group of firms with high female shares (β_1), while coefficient β_2 in model M5 reports the difference between firms with low female shares and the reference group. The three-way interaction $\left(Covid_t \times EL_i \times lowfemaleshare_i\right)$ in model M6 provides the heterogeneous effect of the pandemic on firms training shares, both by E-learning and the female share of firms. The coefficient β_1 in model M6 provides the change in training for the reference group of firms with a low ability to use E-learning and a high female share. The coefficients β_2, β_3, and β_4 in model M6 provide the difference to the change of the reference group by the E-learning and female share characteristics of firms. When estimating fixed effects regressions with ordinary least squares, the sums of the respective beta coefficients are equal to the marginal effects for firms with different characteristics with respect to the economic situation, E-learning, and the female share. To ease the interpretation, I also report marginal effects for

firms with different characteristics, reporting the change in training between 2019 and 2020 for the respective combination of characteristics. I report tests of statistical significance of the differences between coefficients in Tables S-5 and S-6 in the appendix. X_{it} is a set of firm level controls, μ_i denotes the firm fixed effect and ϵ_{it} the idiosyncratic error term.

While the first equation (M1) investigates a simple difference in firms' training shares between the period before and during the COVID-19 pandemic, the subsequent equations provide a more complex setting. In a difference in difference setup, the outcome of interest should trend in parallel comparing the treatment and control groups (Angrist and Pischke 2009, p. 171f). Applied to our case, training shares of firms with increasing demand should evolve in parallel with training shares of firms with unchanged or decreasing demand (M2). Training shares of firms with a high ability to use E-learning should evolve in parallel to shares of firms with a low ability to use E-learning (M3), and training shares of firms with low shares of female employees should evolve in parallel to those of firms with high shares of female

Table 2 Development of training shares by firm characteristics

Share of trained workers (%)	(1) 2016 mean	(2) 2019 mean	(3) 2020 mean	(3)–(2) Diff. PP	Decrease in %
Overall	35.81	35.78	27.73	−8.04	22.48
Product demand during COVID					
Decrease	32.27	30.88	19.74	−11.14	36.08
Unchanged	39.98	38.63	30.55	−8.09	20.93
Increase	34.13	36.24	30.31	−5.93	16.36
E-learning use					
Comparison	33.91	33.38	24.54	−8.84	26.49
E-learning user	47.99	50.45	47.32	−3.14	6.22
Female share within firms					
Low	28.10	28.33	21.31	−7.02	24.77
High	40.79	40.41	31.73	−8.68	21.48
E-learning users: Product demand during COVID					
Decrease	37.30	37.22	26.65	−10.58	28.42
Unchanged	41.96	40.58	32.02	−8.57	21.11
Increase	40.22	42.37	36.70	−5.67	13.39
Comparison: Product demand during COVID					
Decrease	24.59	21.55	9.58	−11.97	55.56
Unchanged	34.71	33.07	26.35	−6.72	20.32
Increase	21.84	22.88	16.40	−6.48	28.32
E-learning users: Female share within firms					
Low	33.72	34.86	27.05	−7.81	22.40
High	44.21	43.82	35.85	−7.98	18.20
Comparison: Female share within firms					
Low	17.72	15.87	10.36	−5.51	34.73
High	33.18	32.44	22.12	−10.33	31.83
Ratio EL/Comparison: Product demand during COVID					
Decrease	1.52	1.73	2.78	1.05	−61.06
Unchanged	1.21	1.23	1.22	−0.01	0.99
Increase	1.84	1.85	2.24	0.39	−20.83
Ratio EL/Comparison: Female share within firms					
Low	1.90	2.20	2.61	0.41	−18.89
High	1.33	1.35	1.62	0.27	−19.99

Data are weighted with cross-sectional weights. The training shares within firms are shown in column 1 for the year 2016, column 2 for 2019, and column 3 for 2020, when the COVID-19 pandemic began in March 2020 in Germany. Column 4 shows the difference between the training share in 2020 and 2019 in percentage points. The rightmost column 5 shows this difference in percentages. The sum of, e.g., columns 4 and 2 can slightly differ from the value in column 3 due to rounding of the statistics

Source: Own calculations using the second wave of IAB-ZEW-Labor Market 4.0-Establishment Survey

employees (M5). Equations M4 and M6 correspond to a triple difference estimator, where it is not required for all underlying trends to be parallel for the estimator to be unbiased. This estimation strategy only requires one parallel trend assumption in ratios of the outcome between groups (Olden and Møen 2022). Applied to equation M4, we assume that the ratio of training shares between the E-learners and the comparison group evolves in parallel within demand groups. For equation M6, parallel trends should hold for the ratio of training shares between E-learners and the comparison within firms with low and high shares of female employees. All descriptive trends are reported in Table 2, including the ratios of training shares by E-learning status.

As reported in the subsequent section, the variables on the economic situation during the crisis, the E-learning use, and the female share are time constant. Therefore, the models do not include the main terms of these variables, as these are canceled out in fixed effects regressions for variables without within-unit change. Table S-3 in the appendix provides between and within standard deviations of the dependent and independent variables of the estimation sample consisting of a balanced panel of 1555 establishments for the years 2019 and 2020. While the dependent variable $Train_{it}$ varies between and within firms, the independent variable $Covid_t$ only varies within firms, and the independent variables $Demand_i$, EL_i, and $lowfemaleshare_i$ only vary between firms. To ease the interpretation of the results, I report marginal effects on the training share. I restrict the sample to the years 2019 and 2020, as I am interested in the change in training right before and after the COVID-19 pandemic began, but use the information for training shares in the year 2016 for robustness checks.

5 Results

5.1 Descriptive results

Table 2 shows the development of the share of trained workers within firms from 2016 to 2020.[2] Columns 1–3 provide the percentage of all employees within a firm who participated in at least one training course for the years 2016, 2019, and 2020. Column 4 provides the difference in training share between the years 2020 (column 3) and 2019 (column 2). The rightmost column provides the relative change in training between 2020 and 2019. In the rows, Table 2 reports these statistics by several firm characteristics.

The overall share of trained workers in the first row of Table 2 was around 36 percent in 2016 and 2019. In 2020, at the beginning of the COVID-19 pandemic, the share of trained workers decreased by 8.04 percentage points to 27.73 percent. This is a substantial decrease of 22.48 percent associated with the COVID-19 pandemic and descriptive evidence for an overall decrease in the training activities of firms during the pandemic. Table 2 provides descriptive evidence for a demand-driven change in training, as firms that faced decreasing demand for the products or services they offer reduced training by 36.08 percent compared to firms that faced increasing demand with a 16.36 percent decrease. While this provides first descriptive evidence for hypothesis 1 that a firm's economic situation is a mediator of the effect of the COVID-19 pandemic on training activities, even those firms that experienced positive economic development during the COVID-19 pandemic substantially reduced their training activities.

To consider the role of E-learning in changes in training during the pandemic, Table 2 shows the training development for firms that have a low ability to use E-learning ("Comparison") and for firms that have a high ability to use E-learning to train their workforce. The comparison group faced a decrease in training of 26.49 percent, while the E-learning group reduced training by only 6.22 percent. This provides descriptive evidence for hypothesis 2 that firms using E-learning are more able to maintain training.

Also, Table 2 reports the training share of firms with low and high female shares. Firms with low female shares reduced training by 24.77 percent between 2019 and 2020. With a decrease of 21.48 percent in training, firms with predominantly female employees show a similar pattern, even though the absolute decrease in percentage points is higher for this group.

As described in Sect. 4.3, the main underlying assumption of the analytical strategy is the parallel trends assumption. With respect to the trends before 2020, Table 2 shows that overall, training shares remained constant between 2016 and 2019 at around 35.80 percent. Considering firms' product demand during COVID, the training shares of firms with decreasing and unchanged demand faced small decreases of around 1.40 percentage points, while the training share of firms with increasing product demand shows an increase of 2.11 percentage points between 2016 and 2019. With respect to firms' E-learning use, the comparison group shows a minor decrease in training share of 0.53 percentage points, while the E-learning group shows a 2.46 percentage point

[2] The training share is measured retrospectively, which might lead to measurement bias. For firms that took part in both waves of the survey (wave 1 in 2016 and wave 2 in 2021/22), I can compare the training share for 2016 retrospectively measured in wave 2 to the actual training share measured in wave 1. With around 33.15 percent, the actual training share surveyed in wave 1 is around 1.73 percentage points higher than the retrospective share measured in wave 2, with around 31.41 percent. However, using a t-test, this difference is not statistically significant. Furthermore, as the year 2016 is excluded in the multivariate analysis because I investigate the difference in training share between 2019 and 2020, recall bias is likely to be even smaller as the survey took place in 2021/22.

increase between 2016 and 2019 before the COVID-19 pandemic. Firms with low and high shares of female employees report stable trends between 2016 and 2019 at around 28 and 40 percent.

We investigate the role of E-learning use by firms' product demand and female shares by estimating a three-way interaction between a dummy for the pandemic and for E-learning use and a categorical variable for firms' product demand (respectively a dummy for firms with low and high shares of female employees). This corresponds to a triple difference estimator requiring a parallel trend assumption in ratios of the outcome variable between groups (Olden and Møen 2022). The ratios between E-learning firms and the comparison group for firms with unchanged or increasing product demand show flat trends of around 1.20 and 1.80. For firms with decreasing demand, the ratio increases from 1.52 in 2016 to 1.73 in 2019, driven by a decrease in the training share of firms in the comparison group from 24.59 to 21.55 percent prior to the pandemic. The ratio between E-learning firms and the comparison group for firms with low female shares increases from 1.90 to 2.20, driven by an increase in the E-learning group and a decrease in the comparison group between 2016 and 2019. The ratio for firms with high female shares remains constant between 2016 and 2019.

Considering the parallel trends assumption underlying the analytical strategy, the assumption is not perfectly fulfilled in all cases. While the economic size in the divergence between trends is rather small, Sect. 5.4 on robustness acknowledges this issue by estimating a placebo test for the difference in training shares using the years 2016 and 2019 (Table S-8) and purging the training shares between 2019 and 2020 by the pre-trend between 2016 and 2019 (Table S-9).

Figure 2 shows the training development for firms with increasing product demand and E-learning (solid black line) compared to all other firms (dashed black line). Between 2016 and 2019, firms with increasing demand and E-learning use (solid black line) had a higher training share, at around 60 percent. Between 2019 and 2020, there was no change in training share. Contrastingly, the comparison group (dashed black line) experienced a lower level of training share in 2016 with around 42 percent, flat pre-trends prior to 2020, and a sharp decline in training in 2020. The dashed gray line provides the counterfactual training trend for the solid black line, which is the development of the comparison group set to the 2016 level of the solid black line. This provides an insight into the counterfactual development of this group in the absence of increasing demand and E-learning use. Firms that faced increasing product demand and used E-learning seem to have been able to maintain training activities far better than the comparison group with less advantageous characteristics.

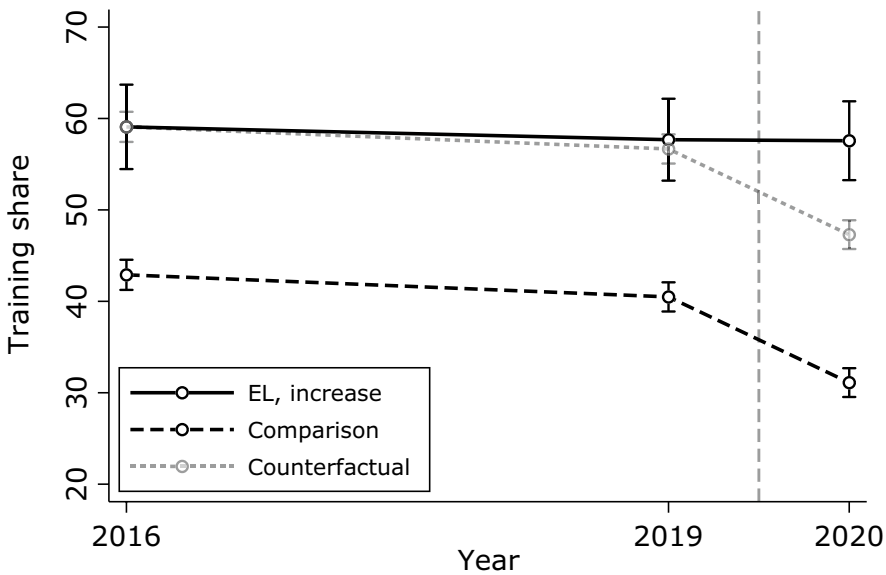

Fig. 2 Training development of E-learner group with increasing demand and other firms. Data are weighted with cross-sectional weights. 95% Confidence intervals. The plot shows the training shares within firms for the years 2016, 2019, and 2020. The solid black line provides the training shares of firms that faced increasing demand for products or services they offer and have a high ability to use E-learning. The dashed black line shows the training shares for all other firms. The gray line with short dashes provides the counterfactual training trend, which is the black dashed line for the controls set to the level of training of the solid black line in 2016. Source: Own calculations using the second wave of IAB-ZEW-Labor Market 4.0-Establishment Survey

Table 3 Interaction and marginal effects on training share (M1—M4)

Dependent variable Training share	(M1)	(M2)	(M3)	(M4)
Interaction effects				
Covid/Reference	−7.054***	−9.189***	−7.902***	−9.245***
	(0.496)	(0.984)	(0.537)	(1.063)
Covid x Unchanged		1.533		1.035
		(1.255)		(1.362)
Covid x Increase		3.909**		2.486#
		(1.202)		(1.330)
Covid x E-learner			4.848***	0.343
			(1.211)	(2.618)
Covid x Unchanged x E-learner				3.176
				(3.487)
Covid x Increase x E-learner				6.404*
				(3.080)
Marginal Effects				
Overall effect	−7.054***			
	(0.496)			
Effect by demand				
Decrease		−9.189***		
		(0.984)		
Unchanged		−7.656***		
		(0.827)		
Increase		−5.280***		
		(0.714)		
Effect by E-learning				
Comparison			−7.902***	
			(0.537)	
E-learner			−3.054**	
			(1.114)	
Effect for comparison by demand				
Decrease				−9.245***
				(1.063)
Unchanged				−8.210***
				(0.885)
Increase				−6.759***
				(0.815)
Effect for E-learner by demand				
Decrease				−8.902***
				(2.419)
Unchanged				−4.691*
				(2.146)
Increase				−0.0118
				(1.392)
Within R2	0.142	0.148	0.150	0.157
Firm-years	3110	3110	3110	3110

Standard errors in parentheses

# $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The columns show the results of separate regressions described by models M1 to M4. All regressions include fixed effects at the firm-level, clustered standard errors at the firm-level, and control for the logarithms of the age and skill structure within firms, the logarithms of worker inflows and outflows within firms, and the logarithm of the wage sum of firms. Table S-4 shows the full the full regression output, including the coefficients of the controls. Table S-5 in the appendix reports the *p*-values of tests for the statistical significance of differences between the reported marginal effects. Table S-7 reports the results with weighted data

Source: Own calculations using the second wave of IAB-ZEW-Labor Market 4.0-Establishment Survey

5.2 Main results

Table 3 provides the interaction effects of a COVID dummy, a categorical variable capturing the economic situation of firms during the pandemic and a dummy for firms' ability to efficiently use E-learning. The lower section of Table 3 provides the marginal effects on the training share based on the interaction effects.

The dependent variable of the regressions in Table 3 is the share of trained workers within a firm for the years 2019 and 2020. All estimations use standard errors clustered at the firm-level, control for age and skill structure, worker inflows and outflows, the wage sum of firms, and include fixed effects at the firm level. The estimation sample consists of 3110 firm-years, which are the observations of 1555 firms for the years 2019 and 2020. The first column of Table 3 shows the effect of a dummy for the year 2020 on the training share within firms. The regression reports that the training share within firms on average decreased by 7.054 percentage points from 2019 to 2020. The second column of Table 3 shows the heterogeneity of the COVID effect by the demand for the products or services firms offer. Firms that faced decreasing demand during the pandemic decreased training by 9.189 percentage points. With a decrease of 7.656 percentage points (indicated by the marginal effect in the lower section of Table 3) firms with unchanged product demand do not differ statistically significant from this groups (indicated by the statistically insignificant interaction effect in the second row of column M2). Firms facing increasing product demand decreased training by 5.280 percentage points, differing statistically significant from the reference group (indicated by the significant interaction effect in the third row of column M2). Table S-5 in the appendix reports the *p*-values of tests for the statistical significance of differences between the marginal effects, reporting that the difference between the marginal effect for increasing demand and for decreasing and unchanged demand is statistically significant at the 1-percent level. This is evidence for the first hypothesis that firms reduced training due to their economic situation during the COVID-19 pandemic.

The third column of Table 3 reports the heterogeneity of the COVID effect by firms' E-learning use. Firms that have a low ability to use E-learning (comparison) decreased training in 2020 compared to 2019 by 7.902 percentage points. Firms in the E-learning group reduce training 4.848 percentage points less than the comparison group (interaction effect in the top section of column M3). This difference is statistically significant at the 0.1-percent level. The E-learner group only decreased training by 3.054 percentage points (marginal effect in the bottom section of column M3). This is evidence for the second hypothesis that firms that are able to use E-learning for training are more resilient with respect to their training activities during the COVID-19 pandemic.

The fourth column of Table 3 combines both mechanisms and reports the heterogeneity of the COVID-effect by product demand and the use of E-learning. Firms that faced decreasing product demand and are in the comparison group reduced training by 9.245 percentage points, and firms that faced unchanged product demand and are in the comparison group reduced training by 8.210 percentage points. With a decrease of 8.902 and 4.691 percentage points for firms that faced decreasing or unchanged product demand but are in the E-learning group, these groups experience similar changes in training (also indicated by the insignificant interaction effects in the top section of Table 3). With a decrease of 6.759, firms that faced increasing product demand and are in the comparison group do not significantly differ from firms that faced decreasing or unchanged product demand within the comparison group. However, the group of firms using E-learning and facing increasing demand (last coefficient in column M4) does not show a decrease in training (with a marginal effect of 0.012). The coefficient for this group differs statistically significant from all other marginal effects in Model M4, besides the coefficient for E-learning users and unchanged demand, only showing a statistically significant difference at the 10-percent level.

Table 4 investigates the demand side of firms' training activities by considering the gender composition within firms. The top section of column M5 in Table 4 reports that firms with predominantly female employees in 2019 (above 50 percent) decreased training by 9.606 percentage points. The decrease in training was less pronounced for firms with a low female share in 2019 (indicated by the highly statistically significant interaction effect of 4.101 in column M5). Column M6 in Table 4 shows an interaction between a COVID dummy, the gender shares, and the E-learning use of firms. In the comparison group, firms with predominantly female employees experienced a decrease in training of 10.720 percentage points (first row in column M6), while firms with a low female share decreased training by 4.486 percentage points less (second row in column M6). In the group with access to E-learning, there is no statistically significant difference by female share (also indicated by the *p*-values in Table S-6). Based on this firm level analysis, training opportunities seemed to deteriorate, especially for females without access to E-learning. E-learning might have provided especially females the opportunity to align their demand for training during times of deteriorating child care provision.

Table 4 Interaction and marginal effects on training share (M5-M6)

Dependent variable Training share	(M5)	(M6)
Interaction effects		
Reference	−9.606***	−10.720***
	(0.864)	(0.966)
Covid x Low female share	4.101***	4.486***
	(1.021)	(1.134)
Covid x E-learner		6.037**
		(1.976)
Covid x Low female share & E-learner		−1.765
		(2.462)
Marginal Effects		
High female share	−9.606***	
	(0.864)	
Low female share	−5.505***	
	(0.575)	
Comparison		
High female share		−10.720***
		(0.966)
Low female share		−6.230***
		(0.616)
E-Learner		
High female share		−4.679**
		(1.751)
Low female share		−1.958
		(1.398)
Within R2	0.152	0.161
Firm-years	3110	3110

Standard errors in parentheses

*# p < 0.10, *p < 0.05, **p < 0.01, ***p < 0.001*

The table shows the interaction effects and marginal effects given by model M5 and M6. The regression includes fixed effects at the firm level, clustered standard errors at the firm-level, and control for the logarithms of the age and skill structure within firms, the logarithms of worker inflows and outflows within firms, and the logarithm of the wage sum of firms. Table S-4 shows the full the full regression output, including the coefficients of the controls. Table S-6 shows the results using weights. Table S-6 in the appendix reports the *p*-values of tests for the statistical significance of differences between the reported marginal effects

Source: Own calculations using the second wave of IAB-ZEW-Labor Market 4.0-Establishment Survey

Table 5 Descriptive statistics of most disadvantaged and advantaged firms

	Decrease, no E-learning	Increase, E-learning	*t*-test
	Mean	Mean	*p*-value
Training participants (%)	27.73	51.91	0.000
Employment structure			
Low qualified (%)	15.03	10.43	0.245
Medium qualified (%)	68.27	53.04	0.000
High qualified (%)	16.70	36.53	0.000
Other characteristics			
Fulltime employees (%)	49.47	64.81	0.001
Female employees (%)	54.92	55.73	0.903
Median wage	93.78	127.57	0.000
Firms	317	134	451

Data are weighted with cross-sectional weights. The shares within firms are shown in column 1 for firms facing decreasing demand with a low ability to use E-learning. Column 2 reports the shares for firms that faced increasing demand and have a high ability to use E-learning. Column 3 reports the *p*-value of t-tests for the statistical significance of differences in the means reported in columns 1 and 2. Table S-16 reports the same statistics but shows all other firms in the first column

Source: Own calculations using the second wave of IAB-ZEW-Labor Market 4.0-Establishment Survey

5.3 Reinforcing inequalities in training participation

The COVID-19 pandemic exacerbated existing inequalities in the labor market depending on the share of tasks that can be done from home (Adams-Prassl et al. 2020). While the nature of occupational tasks is closely linked to their transferability to the virtual space, highly digitized organizational environments insure workers against the economic downturn during the pandemic (Gathmann et al. 2023). The specific impact of the COVID-19 pandemic on labor market inequalities typically favors higher-paying jobs (Dingel and Neiman 2020) while exacerbating preexisting inequalities for disadvantaged groups (Cortes and Forsythe 2023). While digital technologies shield especially higher-skilled workers from the negative employment effects of the pandemic (Oikonomou et al. 2023), lower-skilled workers face a double disadvantage by suffering not only employment decline but also the exacerbation of existing inequalities in training opportunities (Paciorek et al. 2021). To investigate further whether the specific effect of the COVID-19 pandemic found in this study relates to the notion of exacerbating inequalities in training opportunities, I compare the descriptive statistics of firms most resilient to the impact of the pandemic in terms of training activities with those of firms most vulnerable with respect to the effect of the COVID-19 pandemic on training.

Table 5 clearly shows that firms that faced increasing product demand and had a high ability to use E-learning differ in firm characteristics from firms that faced decreasing product demand and had a low ability to use E-learning. These firms, on average, employ higher educated workers, have higher shares of full-time employees, and have a higher median wage. This hints at important dimensions of inequality in training: Low-skilled, lower-paid workers in part-time employment face increasing inequality in training opportunities (O'Connell and Byrne 2012). These inequalities are fostered by ongoing

technological change (Müller 2024) and might have increased during the COVID-19 crisis.

While the role of E-learning in the effects of the COVID-19 pandemic on training constitutes a fault line dependent on the ability of firms to use E-learning for training, the use of E-learning might be a double-edged sword in itself. Digital technologies affect inequalities in work and social life (Olliere-Malaterre et al. 2019). To get insights into the role of E-learning in future work, a comparison with WFH seems promising. Similar to WFH (Barrero et al. 2021), the use of E-learning is likely to stick even after the COVID-19 pandemic. Hereby, the use of E-learning for firms' training activities promises to open up access to training for labor market participants relying on WFH due to, e.g., care responsibilities (Amuedo-Dorantes et al. 2023), but might also be an additional burden to employees if assigned outside of working hours (Yang et al. 2023). This latter argument is especially relevant to employees facing additional burdens outside of work life, e.g., from care responsibilities. While E-learning might offer training opportunities to this group by providing flexibility with respect to time and place, the possibility to taking part in training from any location and also outside of working hours might pose an additional burden, especially for employees with care responsibilities.

5.4 Robustness

A concern with the analytical strategy is that the trends might vary for different groups. A visual inspection of pre-trends in Fig. 2 provides evidence for the parallel trend assumption. To further explore this assumption, I estimate a placebo test for the difference in training shares for the years 2016 and 2019. While I do find statistically significant marginal effects (see Table S-8 in the appendix), these are rather irrelevant with respect to economic size compared to the effects in Tables 3 and 4 in the main text. Investigating the adjusted R-square, the models have little explanatory power for changes in training share between 2016 and 2019. Still, this provides evidence that there is heterogeneity considering the trends prior to 2020, which might confound the effects found in this paper. To test whether the patterns are driven by trends in training prior to 2020, I recalculate the results by purging the 2020 training share of the pre-trend difference between the years 2019 and 2016, ending up with the same conclusion as the main specification (see Tables S-9 in the appendix). Therefore, diverging trends before 2020 are unlikely to change the results in a meaningful way.

Another concern with the estimation strategy using fixed effects regression is clustering at zero in the outcome variable. Using a Tobit regression with firm level dummies shows that the results are substantially the same as the estimation strategy used in the main text (see Table S-10).

Considering effect heterogeneity, the pattern prevails in the production and service sectors for models M1 to M6 (see Tables S-11 to S-13 in the appendix) and for smaller and larger firms (see Tables S-14 and S-15 in the appendix). As the survey item underlying the E-learning measure does not differentiate between the importance of E-learning before and since the pandemic, I conduct the analysis for a subsample of firms that participated in the first survey wave in 2016 and the second wave in 2021/22. Based on these repeaters, I define two groups: Firms that have the same E-learning status in both waves (stayers) and firms that changed from the comparison group in 2016 to the E-learning group in 2021/22 (switchers). Similar to the main analysis, both stayers and switchers benefit significantly from access to E-learning (see Table S-18 in the appendix).

6 Conclusion

This paper shows the increasing importance of E-learning and demonstrates inequality in access to the use of E-learning. Higher qualified full-time employees with higher wages had superior access to E-learning, as they are oftentimes employed in firms facing smaller or no break-ins in training during the pandemic. As qualification and job quality were already known dimensions of inequality in training participation even before the pandemic, this suggests that the COVID-19 pandemic might have reproduced and even increased inequality in training participation. As it is unlikely that the use of E-learning will return to pre-pandemic levels, this might also imply a persistent increase in inequality in training participation along the aforementioned characteristics.

Furthermore, the results suggest that female employees faced greater challenges in training participation, especially in the absence of E-learning. Studies on individual level likewise find a decrease in the training participation especially for females (Kleinert and Zoch 2023). While this is in line with increased care responsibilities during the pandemic, future research on individual level should investigate whether the flexibility offered by the E-learning format helps working individuals with care responsibilities to participate in E-learning and whether this is at the cost of additional burdens due to the dissolution of time and space boundaries with respect to training activities. Future research should therefore investigate the role of E-learning in reducing inequality in training opportunities beyond the context of the COVID-19 pandemic. Additionally, research should investigate whether E-learning provides similar learning opportunities compared to face to face courses.

This study has limitations. First, using the IAB-ZEW-Labor Market 4.0-Establishment Survey (Hanebrink et al. 2021), I am able to measure the training shares for the years 2016, 2019, and 2020 retrospectively. As the survey was collected in 2021/22, it does not include the training share for the year 2021. Therefore, the COVID-19 pandemic only partially affected the measures for the year 2020, as the first measures affecting the labor market took place in March 2020. Therefore, the full impact of the COVID-19 pandemic on the training activities of firms can be expected to be larger, as I can only consider the first 9 months of the COVID-19 pandemic. Second, the E-learning variable does not measure the actual use of E-learning, but if firms increasingly use E-learning for conducting training measures. Comparing the responses of the first and second waves of the survey in Table S-17 in the appendix allows to observe whether firms made use of E-learning already in 2016. The table shows that most either stayed in the comparison group or moved to the E-learning group. Only few firms switched from E-learning to the comparison group. Therefore, the E-learning variable is a good proxy for the actual training regime within firms. Furthermore, the switchers from E-learning to the comparison group contribute to an underestimation of the effect, as these are firms with E-learning contributing to the comparison group. Additional analyses considering the pre-pandemic measure of E-learning for a subset of the sample are in line with the patterns found in the main specification (Table S-18 in the appendix).

In terms of policy implications, this study shows that the COVID-19 pandemic resulted in a specific impact on training activities, especially affecting firms with limited opportunities to efficiently use E-learning. The employment structure of those firms suggests that these firms employ individuals who already faced disadvantages in training participation even before the pandemic. As the impact of the COVID-19 pandemic can be expected to be ongoing, providing training opportunities targeted at these individuals (lower-qualified individuals typically in low-quality jobs) is of utmost importance to ensure the integration of every individual in a changing labor market.

Supplementary Information

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Additional file 1.

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Declarations

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Not applicable.

Consent for publication
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Competing interests
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References

Adams-Prassl, A., Boneva, T., Golin, M., Rauh, C.: Inequality in the impact of the coronavirus shock: evidence from real time surveys. J. Public Econ. **189**, 104245 (2020)
Alipour, J.V., Falck, O., Schüller, S.: Germany's capacity to work from home. Eur. Econ. Rev. **151**, 104354 (2023)
Amuedo-Dorantes, C., Marcén, M., Morales, M., Sevilla, A.: Schooling and parental labor supply: evidence from COVID-19 school closures in the United States. ILR Rev. **76**(1), 56–85 (2023)
Angrist, J.D., Pischke, J.S.: Mostly harmless econometrics: an empiricist's companion. Princeton University Press, Princeton (2009)
Barrero, J.M., Bloom, N., Davis, S.J. Why working from home will stick. NBER Working Paper No. 28731. Cambridge, MA: National Bureau of Economic Research. (2021).
Bartik, A.W., Cullen, Z.B., Glaeser, E.L., Luca, M., Stanton, C.T. What jobs are being done at home during the COVID-19 crisis? Evidence from firm level surveys. NBER Working Paper No. 27422. Cambridge, MA: National Bureau of Economic Research. (2020).
Bellmann, L., Gleiser, P., Kagerl, C., Koch, T., König, C., Kruppe, T., Lang, J., Leber, U., Pohlan, L., Roth, D., Schierholz, M., Stegmaier, J., Aminian, A. Weiterbildung in der Covid-19-Pandemie stellt viele Betriebe vor Schwierigkeiten. Accessed at https://www.iab-forum.de/weiterbildung-in-der-covid-19-pandemie-stellt-viele-betriebe-vor-schwierigkeiten/ (2020). Accessed 5 July 2023.
Bick, A., Blandin, A., Mertens, K.: Work from home before and after the COVID-19 outbreak. Am. Econ. J. Macroecon. **15**(4), 1–39 (2023)
Bloom, N., Davis, S.J., Zhestkova, Y.: Covid-19 shifted patent applications toward technologies that support working from home. AEA Papers Proc. **111**, 263–266 (2021)

Boll, C., Müller, D., Schüller, S.: Neither backlash nor convergence: dynamics of intra-couple childcare division during the Covid-19 pandemic in Germany. J. Labour Mark. Res. **57**(1), 27 (2023)
Collins, C., Landivar, L.C., Ruppanner, L., Scarborough, W.J.: COVID-19 and the gender gap in work hours. Gend. Work Organ. **28**, 101–112 (2021)
Cordes, A., von Haaren, F. Betriebliche weiterbildung in deutschland: auswertungen des IAB-Betriebspanels 2003 bis 2012. Studien zum deutschen Innovationssystem No. 2-2015. Berlin: Expertenkommission Forschung und Innovation (2015)
Cortes, G.M., Forsythe, E.: Heterogeneous labor market impacts of the COVID-19 pandemic. ILR Rev. **76**(1), 30–55 (2023)
Dieckhoff, M.: Does it work? The effect of continuing training on labour market outcomes: a comparative study of Germany, Denmark, and the United Kingdom. Eur. Sociol. Rev. **23**(3), 295–308 (2007)
Dingel, J.I., Neiman, B.: How many jobs can be done at home? J. Public Econ. **189**, 104235 (2020)
Ehlert, M.: Who benefits from training courses in Germany? Monetary returns to non-formal further education on a segmented labour market. Eur. Sociol. Rev. **33**(3), 436–448 (2017)
Flake, R., Janssen, S., Leschnig, L., Malin, L., Seyda, S. Berufliche weiterbildung in zeiten von corona: insgesamt kein dramatischer einbruch, aber deutliche gruppenspezifische Unterschiede. Accessed at https://www.iab-forum.de/berufliche-weiterbildung-in-zeiten-von-corona-kein-dramatischer-einbruch-aber-deutliche-gruppenspezifische-unterschiede/ (2021) Accessed 30 October 2023
Frodermann, C., Grunau, P., Haas, G.C., Müller, D. Working from home in times of the Covid-19 crisis: Extent, challenges and potentials for the future. IAB- Kurzbericht 05/2021. Nuremberg: Institute for Employment Research. (2021)
Ganzer, A., Schmidtlein, L., Stegmaier, J., Wolter, S. Establishment History Panel 1975-2019. FDZ-Datenreport 16/2020. Nuremberg. Institute for Employment Research. (2021)
Gathmann, C., Kagerl, C., Pohlan, L., Roth, D. The pandemic push: digital technologies and workforce adjustments. IZA Discussion Papers No. 16062. Bonn: Institute of Labor Economics. (2023)
Hanebrink, A., Lehmer, F., Müller, C. IAB-ZEW-Labor Market 4.0-Establishment Survey. FDZ-Datenreport 07/2021. (en), Nuremberg: Institute for Employment Research. (2021)
Illing, H., Oberfichtner, M., Pestel, N., Schmieder, J., Trenkle, S. Gender-specific labour market effects of the Covid-19 Pandemic in Germany: Similar employment effects, but higher additional child care burden for mothers (No. 3/2022). IAB-Kurzbericht. https://doku.iab.de/kurzber/2022/kb2022-03.pdf (2022). Accessed 2 July 2023
International Labour Office. Skills and Employability Branch. Skilling, upskilling and reskilling of employees, apprentices and interns during the COVID-19 pandemic: findings from a global survey of *enterprises.* Geneva: International Labour Office. (2021)
Jost, R., Leber, U. Die betriebliche Weiterbildung ist in der Corona-Krise massiv eingebrochen. Accessed at https://www.iab-forum.de/die-betriebliche-weiterbildung-ist-in-der-corona-krise-massiv-eingebrochen/ (2021). Accessed 30 October 2023
Kleinert, C., Zoch, G.: Polarizing or reducing unequal participation opportunities? Impact of the COVID-19 pandemic on adult vocational learning. Zeitschrift fur Erziehungswissenschaft: Zfe **2023**, 1–30 (2023)
Kleinert, C., Zoch, G., Vicari, B., Ehlert, M.: Work-related online learning during the COVID-19 crisis in Germany. Zeitschrift Für Weiterbildungsforschung **44**(3), 1–18 (2021)
Konings, J., Vanormelingen, S. The impact of training on productivity and wages: firm-level evidence. Review of Economics and Statistics, **97**(2), 485–497 (2015)
Kudyba, S.: COVID-19 and the acceleration of digital transformation and the future of work. Inf. Syst. Manag. **37**(4), 284–287 (2020)
Lee, E.K., Parolin, Z.: The care burden during COVID-19: a national database of child care closures in the United States. Socius **7**, 23780231211032028 (2021)
Müller, C.: Technological change, training, and within-firm wage inequality in Germany. Eur. Sociol. Rev. **40**(3), 450–463 (2024)
O'Connell, P.J., Byrne, D.: The determinants and effects of training at work: Bringing the workplace back in. Eur. Sociol. Rev. **28**(3), 283–300 (2012)
Oikonomou, M., Pierri, N., Timmer, Y.: IT shields: technology adoption and economic resilience during the COVID-19 pandemic. Labour Econ. **81**, 102330 (2023)
Olden, A., Møen, J.: The triple difference estimator. Economet. J. **25**(3), 531–553 (2022)
Ollier-Malaterre, A., Jacobs, J.A., Rothbard, N.P.: Technology, work, and family: digital cultural capital and boundary management. Ann. Rev. Sociol. **45**, 425–447 (2019)
Paciorek, A., Manca, F., Borgonovi, F.: Adult learning and COVID-19: How much informal and non-formal learning are workers missing? OECD, Paris (2021)
Yang, D., Kelly, E.L., Kubzansky, L.D., Berkman, L.: Working from home and worker well-being: new evidence from Germany. ILR Rev. **76**(3), 504–531 (2023)

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