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The employment effects of raising negotiated minimum wages for apprentices

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Abstract

This study examines the employment effects of raising the minimum wages for underage apprentices in Germany. To estimate our effects, we exploit age-, sector-, and state-level variations of negotiated minimum wage increases within a triple difference framework. Using a full sample of apprenticeship contracts, we find negative employment effects, as the number of training contracts for underage apprentices decreases significantly due to the minimum wage adjustments. Furthermore, we find that the negative employment effect increases with the size of the minimum wage adjustments. The effects are mainly driven by a reduction in contracts for low-qualified training applicants and for sectors where firms mainly follow a substitution- rather than an investment-oriented training strategy.[1]

Keywords: Minimum wage, Apprenticeship market, Collective bargaining
JEL Classification: J31, J23, J38, J51, J2

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1 Introduction

Many of the published studies on minimum wages focus on certain groups of workers, on specific industries and regions or on the labour market as a whole. Despite the fact that several countries have implemented minimum wages specifically for apprentices (for example, France, UK, Ireland, Belgium and Australia, see Adema et al., 2019), the employment effects in the market for apprenticeships have not yet been explored. Given the essential role of the apprenticeship systems in providing non-college bound youth with marketable skills in many industrialised economies, the lack of evidence for this segment of the youth labour market is surprising.

This study addresses this gap in the literature by building on a natural experiment that occurred in Germany in the years between 2006 and 2018 and which lead to an exogenous adjustment of apprenticeship wages. In Germany, minimum wages for apprentices are negotiated by unions and employers during the collective bargaining process.[2] For many years, collective agreements in certain sectors and regions fixed lower wage-levels for apprentices under the age of 18 (in the following U-18) than for apprentices of 18 years or older (in the following O-18). In 2006, an anti-discrimination law banned the unequal setting of wages based on differences in age. This resulted in substantial increases in the minimum wage for U-18 apprentices in the years after implementing the new law.

Owing to region-specific differences in age-related minimum wages and sector-specific time lags in updating collective agreements, we observe the wage adjustments in different regions and sectors at different points in time. Our econometric framework takes advantage of this quasi-experimental setting by applying a triple difference (DDD) approach that allows for time-specific heterogeneous treatment effects.

To develop our hypothesis about the direction of the employment effects, we draw on aggregate data describing the firm-structure and competitiveness of the sample sectors in this study. Due to a high number of small firms, a low market concentration and a predominantly substitution-oriented firm training strategy in the sample sectors, we expect a negative employment effect of an increase in the minimum wage for apprentices. Using an administrative full sample of training contracts, we find that the upward adjustments of U-18 minimum wages indeed result in a significant reduction in the number of U-18 training contracts. The decrease in the number of contracts is especially severe for applicants with no or a lower schooling degree. We also show that negative employment effects increase in the size of the minimum wage adjustment, notably in sectors in which firms follow a substitution rather than an investment incentive for

[2]In principle, collectively bargained wages for apprentices are binding for both covered and non-covered firms. However, according to court law, non-covered firms may deviate from the collectively bargained wage by no more than 20 percent.

training. However, we do not find substantial negative effects on the separation rate of apprentices.[3]

Our study contributes to the literature in at least three ways. First, we provide new evidence on the employment effects of minimum wage adjustments in the market for apprenticeships. Second, because minimum wages are negotiated during the collective bargaining process, we contribute to the literature on the importance of bargaining institutions for (labour) market adjustments. Finally, our study exploits a unique setting of an exogenous staggered minimum wage adjustment over time, region and groups of apprentices to identify the employment effects. Such a setting is rarely observed in previous studies on the effects of minimum wages. Given the central role of apprenticeships in generating a skilled workforce especially in continental European countries, our results also have important implications for policy makers.

The remainder of this study is structured as follows. Section 2 describes wage-setting schemes in the apprenticeship system and our source of exogenous variation. Section 3 provides a theoretical embedding and overview of the related literature. Section 4 presents the empirical strategy. Section 5 provides information on the data sources and descriptive statistics. Section 6 presents the results, including an analysis of the timing of effects (Section 6.3), and further robustness checks (Section 6.4). Section 7 concludes the study.

2 Institutional setting

For young adults in Germany, the apprenticeship system is the most frequent pathway into the labour market. It is highly regulated in that the curricula of training occupations are recognised at the national level, and firms commit to the provision of training according to the respective occupational curriculum (Dustmann and Schoenberg, 2012). The training period lasts between two and three and a half years, ending with an external final exam and a certificate acknowledging the former apprentice as a skilled worker. The programme is split between working and learning for three to four days in the training firm and attending a vocational school for the remaining days of a working week. Before starting an apprenticeship, the firm and apprentice sign a training contract that specifies working conditions, probation periods, and holiday entitlements. It also defines the apprentice wage for the entire training period, whereas wages increase annually.[4]

Generally, collective bargaining agreements have broad coverage and create significant standardisation in wages and working conditions in Germany (see Jaeger et al.,

[3]Separations measure the termination of a contract before taking the final exam, which can be both the result of the apprentice quitting or the establishment terminating the contract.

[4]See Muehlemann et al. (2010) for a detailed description of the institutional setting.

2022). Collective agreements for apprentices are part of the general collective bargaining process and play a special role in setting the apprentice wage. Although training firms are, by law (§17 BBiG[5]), mandated to pay their apprentices an appropriate training compensation, employer associations and unions bargain over minimum wages applicable to a respective sector and region.[6] If a firm is subject to a collective agreement, the negotiated minimum wage represents the minimum wage to be paid to apprentices. In 2007, this applied to more than half of German establishments (54.2%) and approximately two-thirds of German apprentices (64.5%) (Beicht and Walden, 2012). While according to law, non-covered firms may deviate by no more than 20% from the negotiated wages, Ellguth and Kohaut (2021) document that approximately 30% of uncovered firms voluntarily comply with negotiated minimum wages and do not use the 20% clause. Hence, although collectively bargained apprentice wages do not directly apply to all firms, negotiated minimum wages constitute a legally binding benchmark.

For many years, some collective agreements fixed lower minimum wages for apprentices below 18 years. Beicht and Walden (2012) and a survey that we conducted ourselves confirm that the appropriateness of apprenticeship pay was regarded as being connected to the cost of basic needs of apprentices which supposedly increases when becoming an adult. Those so-called *youth deductions* have historical roots and have existed for decades (Kocher, 2015). Between 2008 and 2019, such youth deductions applied to collective agreements in 16 sectors and 12 of the 16 federal states (see Table 1). While several youth deductions existed in specific states only, regulated deductions in roofing, aviation (Lufthansa), and landscaping applied to all federal states.

Table 1 lists all sectors and regions to abolish the youth deductions and adjust the negotiated minimum wage for U-18 apprentices upward to that of O-18 apprentices between 2008 and 2019. Hereafter, we refer to these respective state and sector cells as *treated*.

Youth deductions in apprentice minimum wages were abolished because of the enactment of the General Equal Treatment Act[7] (AGG) in 2006. The AGG was enacted to stop and prevent discrimination based on ethnicity, gender, religion, belief, disability, age, or sexual orientation. It essentially banned age discrimination in wage setting. Furthermore, the AGG could not be repealed by collective wage agreements (§31) and, therefore, affected all new and existing collective agreements, including the area of apprenticeship training (Verdi, 2007).

While the AGG was enacted in 2006, the abolition of youth deductions and the corresponding increase in U-18 minimum wages followed later at different points in time

[5]The Vocational Training Act is the central legislative instrument for apprenticeship training in companies. See `https://www.gesetze-im-internet.de/bbig_2005/__17.html`.

[6]A small number of firm-level bargaining contracts exist in large companies.

[7]See `https://www.gesetze-im-internet.de/englisch_agg/index.html`.

Table 1: Collective agreements with age discriminatory regulations and their abolition between 2008 and 2019

Sector	Federal State	Date of abolition
Agriculture	Saxonia, Saxonia-Anhalt, Thuringia	2011
	Schleswig Holstein, Baden-Wurttemberg	2013
	Hesse	2016
	Bavaria	2018
Horticulture	Bavaria	2015
Tree nurseries	Bavaria	–
Wine growing	Bavaria	–
Forestry	Thuringia	2011
Earths and minerals	Baden-Wurttemberg	–
Concrete	Schleswig Holstein, Bremen, Lower Saxony	2012
Bricks	Baden-Wurttemberg	2018
Fine ceramics	Baden-Wurttemberg	–
Textiles	Hesse, Rhineland Palatinate, Saarland	2013
Clothing	Hesse, Baden-Wurttemberg, Saarland	2013
Roofing	Germany	2008
Hospitality and gastronomy	Bavaria	2014
Motor trades and repairs	Northrhine Westphalia	2012
Aviation	German Lufthansa	2012
Landscaping	Germany	2018

Source: Registry of Collective Agreements of the Federal Ministry of Labour and Social Affairs.

(see Table 1).[8] To gain further clarity on the reasons for delays in adjustments, we conducted a survey among the affected employer associations and unions. Following the survey responses, the reasons for the time lag in adjusting minimum wages were twofold. First, collective bargaining negotiations usually do not take place annually, and the bargaining topics depend on the agenda and priorities of negotiating unions and employers. Second, there has been legal uncertainty concerning the application of AGG to apprenticeships owing to contradictions to The Vocational Training Act.[9]

Given the above information, we argue that the elimination of youth deductions in apprenticeship wages is exogenous to our outcome variables, mainly the employment of apprentices. There is no indication that the adjustment in minimum wages was driven by reasons related to the conditions in the apprenticeship markets at the time of the change or before.

[8]To date, wine growers in Frankonia (Bavaria) still have higher wages for apprentices above 18 years of age.

[9]Respective passages allowing age-based discrimination in the apprentice wage were only eliminated from The Vocational Training Act on 1 January 2020 (see Deutscher Bundestag, 2019). In the survey among the sectors of concrete and roofing, the AGG is directly named as the reason for the abolition. Representatives in hospitality, gastronomy, and horticulture stated that abolition after the AGG took longer, because of legal uncertainties in the Vocational Training Act. In motor trades and repairs, the delay can be attributed to disagreements between social partners and is implemented only after a different union assumed bargaining responsibilities.

3 Related literature

Because collectively bargained minimum wages can be regarded as minimum wages for both covered and non-covered firms in the German apprenticeship market, we first consider the theoretical literature on the effects of minimum wages to build our hypothesis. We then discuss literature on the role of wage costs in the German apprenticeship system. Finally, the section provides a general overview of the empirical literature on minimum wages and the literature on the specific case of young labour market participants and apprentices.

3.1 Wage-setting in competitive and monopsonistic markets

The standard neoclassical model builds on the assumption of profit maximisation under perfect competition and it predicts that a minimum wage above the market-clearing level results in lower employment. However, in monopsonistic labour markets, a moderate minimum wage increase above the monopsonist's profit-maximising wage may increase employment. Hence, the degree of monopsony power is among the main factors that determine the direction of employment effects (see Figure A.1).

Monopsony power in the training market, for example, may arise owing to a small number of employers and collusion, asymmetric information concerning the training content, or frictions because of occupational or geographic immobility (Manning, 2003; Ryan, 2016). Muehlemann et al. (2013) provide evidence for moderate monopsony power of firms over apprentices in Switzerland. As there is no direct empirical evidence on the degree of monopsony power over apprentices in Germany, we build our hypothesis on: a) the distribution by firm size in the sample sectors; and b) an indicator providing revenue shares of market concentration (i.e., the Herfindahl–Hirschman Index (HHI) (Hirschman, 1964)). Apart from the aviation sector, very small and small firms dominate our sample sectors (Table B.2). Furthermore, Figure A.2 shows that market power in the sample sectors is relatively low.[10] Therefore, we expect that the firms in our sample react according to competitive apprenticeship markets to an increase in the U-18 minimum wage, that is, with a reduction in the number of contracts for U-18 apprentices.

3.2 Incentive to train

Apart from the market structure, the training incentive of firms that engage in apprenticeship training may indicate the direction of the expected employment effects of an increase in minimum wages. Firms may have different incentives for training. Assuming that firms behave rational, they weigh the costs against the benefits of training and base

[10] Note that HHI-values are not available for agriculture and horticulture.

their decisions on total net costs. A peculiarity of apprenticeship training is that costs and benefits may arise at various points in time. Initially, firms may incur high costs upfront, for example, in the hiring process and assigning experienced personnel to spend their time training the apprentice. Simultaneously, benefits may be low at the beginning because the productivity of the apprentice only increases with time and the amount of received training. Over time, this relationship may reverse as apprentices become more productive and require less instruction from training personnel. Depending on the overall net cost over the entire training period, a firm may break even or generate profits during the training period. This scenario is referred to as the substitution incentive for training (Lindley, 1975).

However, a firm may also be left with substantial net costs that can only be recovered by continuing the employment of apprentices as a skilled workers. Firms can then profit from compressed wages to recover costs owing to search frictions and the specificity of the training received (Acemoglu and Pischke, 1999a, b). They may also benefit from saved hiring costs, a lower risk of a bad match, and higher productivity of the self-trained worker (Wolter and Ryan, 2011). Firms bearing net-costs but aiming for returns after training follow an investment incentive of training.

In the German context, several empirical studies show that, on average, firms bear net costs when training apprentices (cf. Schoenfeld et al., 2020); that is, German firms invest in training that is transferable to other firms and, therefore, mostly general.[11] However, while average firms in Germany incur net costs, this is not the case for all firms. Net costs and retention of former apprentices are highly heterogeneous, depending on the sector, training occupation, firm size, and other characteristics. Only approximately one-fourth of training firms break even and gain a net benefit during the training period (BIBB Cost-Benefit Survey 2017, cf. Schoenfeld et al., 2020).

Depending on the training incentive, we would expect that a rise in the minimum wage for apprentices affects firms differently. Firms following a substitution-oriented strategy depend on the comparably low unit labour costs of apprentices. Therefore, we would expect that they react more sensitively to an apprentice minimum wage increase than firms that follow an investment incentive. To consider firms' training incentives, we calculate firm-level net training costs and the share of apprentices' retention for the sample sectors. We find that both are mostly below average (cf. Table B.3), indicating that substitution-oriented training dominates the sample sectors.

[11] Acemoglu and Pischke (1999a, b) consider the German "riddle" of general training investment as a starting point for their extension of Becker's human capital theory.

3.3 Empirical evidence on the employment effects of minimum wages

Many empirical studies examine the effects of minimum wage increases on employment. Most studies show no negative or insignificantly small overall employment effects (for example, see Card and Krueger, 1994 and extensive reviews for the UK in Leonard et al., 2014, the US in Doucouliagos and Stanley, 2009, and Germany in Bossler and Gerner, 2020).

Regarding the youth labour market, the majority of studies find negative employment effects of very small size on the margins of statistical significance (Croucher and White, 2011; Allegretto et al., 2017). Hyslop and Stillman (2007) analyse the effects of a large reform of minimum wages affecting youth workers in New Zealand by increasing the youth minimum wage for 16-to-17-year-olds and lowering the eligible age for the adult minimum wage from 20 to 18 years. The authors find evidence for an increase in labour supply of 16-to-17-year-olds, however small employment losses. In 2008, the youth minimum wage in New Zealand was replaced with a new entrants minimum rate for 16-to-17-year-olds, set at 80% of the adult minimum wage. Here, Hyslop and Stillman (2021) find that this abolition resulted in substitution towards 18-to-19-year-olds. Since these effects were mostly borne by students, the authors overall conclude that the minimum wage increase had fairly small adverse effects. Giuliano (2013) examines the firm's response to the 1996 US federal minimum wage increase. She finds evidence consistent with substitution across groups of low-skilled workers as compulsory increases in the relative wages of teenagers led to increases in their relative employment. Kreiner et al. (2020) estimate negative employment effects for teenage minimum wages in Denmark by exploiting a discontinuity at 18 years where the hourly wage increases by 40%. Neumark and Wascher (2004) find in an OECD cross-country study that minimum wages have negative effects on youth employment. However, the existence of employment protection laws and active labour market policies tend to dampen the disemployment effects.

In 2010, the UK introduced the National Minimum Wage (NMW) Apprentice Rate, a sub-minimum wage that applies to all apprentices aged 16 to 18 and to everyone in their first year of the apprenticeship. Apprentices in the second and advanced years of their programme are compensated according to the (age-specific) NMW. Behling and Speckesser (2013) estimate the effect of the introduction of the NMW Apprentice Rate on the wage levels of apprentices. Using difference-in-differences (DD) estimators, the authors find no effect on older apprentices (aged 25 and above) but a statistically significant wage decrease for younger apprentices working in traditional non-low-wage sectors. Papps (2020) analyses whether the NMW Apprentice Rate causally affects the amount of training apprentices receive. He exploits the discontinuity in the NMW

Apprentice Rate for apprentices at the point of reaching the second year of training. In firms compliant with the NMW Apprentice Rate legislation, 19-to-20-year-old apprentices receive a statistically significant decrease in the amount of training provided by firms when they become eligible for a higher age-specific NMW. However, the author focuses on the amount of training for apprentices that are already hired. In contrast to this study, we provide estimates for employment and separation effects of an increase in the negotiated minimum wage.

Taken together and based on both the discussed theoretical frameworks and the results from previous empirical works on minimum wages in other countries, we expect that firms in our sample sectors react sensitively to exogenous upward wage adjustments, resulting in negative employment effects in response to the increased minimum wage.

Besides net employment effects, we also analyse effects on the number of separations. Although there are no studies analysing the minimum wage effect on separations in the apprenticeship market, there is some indication of possible, yet inconclusive effects from the labour market literature studying wages in the US restaurant industry. Hirsch et al. (2015), for instance, find a weak negative relationship between minimum wage increases and turnover rates. Dube et al. (2016) focus on labour turnover of teens in response to minimum wage changes and report that an increased minimum wage significantly reduced separation and turnover rates.

4 Empirical strategy

The key empirical challenge in investigating causal effects of minimum wage increases is estimating counterfactual employment development. We identify the counterfactual by exploiting age- and state-level variations in the minimum wage in the sample sectors using a DDD approach. The DDD approach extends the DD estimator by incorporating a further control group that is completely unaffected by the policy (Berck and Villas-Boas, 2016). Therefore, the DDD design entails an implicit placebo test on apprentices in non-treated states who are unaffected by the minimum wage increase. In the first step, a typical DDD approach compares changes in the employment outcomes of U-18 and O-18 apprentices in treated states. Comparing the two employment trends yields the DD in the treated states. In the second step, this DD is compared with the outcome differences between U-18 and O-18 apprentices over time in the control states, the analogous DD. This allows for the estimation of the average treatment effect of the treated (ATT), which is the difference between the two DD effects.

This standard DDD approach takes the following functional form:

$$\begin{aligned} E_{rstda} =& \alpha + \beta_1 X_{rstda} + \beta_2 \tau_t + \beta_3 \gamma_s + \beta_4 \lambda_r + \beta_5 \text{U18}_a + \beta_6 \text{post}_t \times \text{treated}_s \\ &+ \beta_7 \text{post}_t \times \text{U18}_a + \beta_8 \text{treated}_s \times \text{U18}_a \\ &+ \beta_9 \text{treated}_s \times \text{U18}_a \times \text{post}_t + \epsilon_{rstda}, \end{aligned} \tag{1}$$

where we denote *treated* as 1 for states that formerly had age-related minimum wage differences in a given economic sector, and 0 for the sector-specific control states. $post = 0$ for years with age-related minimum wage differences and $post = 1$ after the U-18 minimum wage is increased. We set $U18 = 1$ for U-18 apprentices, and zero for O-18 apprentices. E_{rstda} is the logarithmic number of apprenticeship contracts for individuals in year t, sector r, federal state s, with school degree d, and age category a (U-18 and O-18). X_{rstda} is a matrix of additional control variables, τ_t are fixed-year effects, γ_s are fixed-state effects, λ_r are fixed-sector effects, and ϵ denotes the error term. The DDD effect (β_9) is estimated using the triple interaction term, which is equal to one for U-18 apprentices in treated states after the minimum wage increases and zeroes otherwise. This reflects the outcome of U-18 relative to O-18 apprentices in treated states relative to control states.

In our case, treatment does not begin simultaneously for all treated states, but occurs sometime between 2008 and 2018, depending on the change in the specific collective agreement (see Table 1). Recent literature shows that estimating Equation 1 in such a staggering treatment setting yields estimates biased in the presence of heterogeneous treatment effects, potentially even showing the wrong sign. Several studies have proposed alternative estimators that aggregate effect heterogeneity more sensibly in settings with staggered treatment times (for example, Callaway and Sant'Anna, 2021; Borusyak et al., 2022; Gardner, 2021).

To account for heterogeneous treatment effects, we use the estimator by Gardner (2021) that is robust to treatment-effect heterogeneity under staggered treatment adoption (see, for example, Mann, 2021 for a recent application in a DDD setting or Ellis et al., 2022 in a DD setting). Gardner (2021) proposes a two-stage estimator where, in the first stage, group and period effects are identified from the sample of untreated observations. After eliminating these group and period effects, the treated and untreated outcomes are compared in the second stage, allowing us to identify the DDD effect, that

is, the ATT.

$$E_{rstda} = \alpha + \beta_1 X_{rstda} + \beta_2 \tau_t + \beta_3 \gamma_s + \beta_4 \lambda_r + \beta_5 \text{U18}_a + \beta_6 \text{treated}_s \times \text{U18}_a + \zeta_{rstda}. \tag{2a}$$

$$\widetilde{E}_{rstda} = \delta + \theta_1 \text{treated}_s \times \text{post}_t + \theta_2 \text{treated}_s \times \text{U18}_a \times \text{post}_t + \eta_{rstda} \tag{2b}$$

To apply this estimator to our DDD framework, we first estimate the explanatory value of all covariates, including time (*post*) and group (*treated*) effects; the first part of Equation 2. Subsequently, we subtract their explanatory values from the outcome variables and regress the residual $\widetilde{E}_{rstda}$ on $treated_s \times post_t$ and $treated_s \times U18_a \times post_t$ in the second stage. Note that we include $treated_s \times post_t$ in the second step to avoid assuming that O-18 apprentices are unaffected by the minimum wage increase in treated states. We estimate the coefficients using a generalised method of moments estimator (GMM) and cluster standard errors at the sector and state levels.

Despite recent advances in the staggered assignment literature, we do not entirely abstain from the standard DDD regression approach as depicted in Equation 1. Apparently, it identifies the treatment effects of interest very generally (Wooldridge, 2021).

It is important to further note that, by design, the DDD model accounts for many possible confounders. Although it essentially performs two DD analyses in one, it does not require two common trend assumptions to hold. It merely requires that, in the absence of treatment, the number of U-18 relative to O-18 contracts in treated states would be the same as their relative outcome in non-treated states (Olden and Møen, 2022). One important aspect of this assumption to hold is that there are no pre-existing differences in the age composition of apprentices. However, Figure A.4 does not reveal any conspicuous pre-policy differences in the age composition between treated and untreated states in the sample sectors. Furthermore, we conduct an event-history analysis to test for pre-trends.

5 Data and descriptive statistics

5.1 Data

For our empirical analysis, we integrate two administrative data sources. Our main data source is The Vocational Education and Training (VET) Statistics of the Federal Statistical Office and the Statistical Offices of the federal states for the period from 2008 to 2019 (Uhly, 2022). The VET Statistics are the only full-count registry of apprenticeship contracts in Germany containing information on apprenticeship con-

tracts regulated by the Vocational Training Act and Craft Trade Act. We calculate the total number of apprenticeship contracts at the level of 2-digit economic sectors of the Statistical Classification of Economic Activities (NACE) for each year.[12] The data further disclose information on occupation, the apprentice's age, and gender, the highest secondary school degree, and previous participation in measures to enhance occupational orientation provided by the Federal Employment Agency (BA). The data also allow us to differentiate whether the apprentice has completed a vocational preparation programme[13] and whether the training establishment fully finances the apprenticeship.

Furthermore, we use the Registry of Collective Agreements of the Federal Ministry of Labour and Social Affairs for information on the minimum wages. This Registry contains the richest collection of data on collective agreements concerning negotiated apprenticeship minimum wages. The registry covers agreements in the 450 most important sectors and sub-sectors. Additionally, we include agreements that became effective but were not yet registered (see Wenzelmann and Schoenfeld, 2020). In addition to the negotiated minimum wages for each apprenticeship year, these data contain the agreements' date of validity, information on the covered economic sectors at the 2-digit NACE level, and the covered regions.

We restrict our sample to the nine sectors that, first, originally had minimum wage differences and, second, are sufficiently large,[14] namely agriculture, horticulture, textiles, clothing, roofing, motor trades and repairs, hospitality, gastronomy, and aviation. The data are aggregated by federal state, sector, secondary school degree, and age group (U-18 and O-18). We further restrict our sample to apprentices in the first year of their apprenticeship that hold either no school degree, a lower school degree (9 years of schooling), or a middle school degree (10 years of schooling). Apprentices with a high school degree (12 or 13 years of schooling) are excluded because only a few high school graduates are younger than 18 years.[15] Additionally, we exclude inter-company (industry-wide) apprenticeships, part-time apprenticeships, apprentices holding a foreign school degree,[16] and contracts with an implausibly shortened apprenticeship period.

As age-related differences in minimum wages were abolished at two different

[12]Note that the information on the economic sector is not available for crafts apprenticeships except for those conducted in the Stuttgart area. We assume that the structure of 2-digit economic sectors are similar for the crafts in all other regions and impute the sector for missing crafts apprenticeships according to the occupation, given the structure of apprenticeships in the Stuttgart area. Note that training firms in the crafts are mainly small and focused on certain occupations of their craft.

[13]The VET Statistics capture preparatory programmes lasting at least 6 months.

[14]Forestry, earth and minerals, concrete, bricks, and landscaping are excluded as they have a fairly low yearly number of contracts.

[15]In 2008 (2019), 0.3% (2.1%) of high school graduates were younger than 18 (data for 2008 are provided on personal demand of the Federal Statistical Office, data for 2019 are from Federal Statistical Office (2020)).

[16]In the VET-Statistics, foreign school degrees cannot be assigned to the corresponding degree in Germany.

times over six federal states in agriculture, we include Schleswig-Holstein and Baden-Wurttemberg, which abolished wage differences in 2013 as treated states and exclude Saxonia, Saxonia-Anhalt, Thuringia, Hesse, and Bavaria which abolished wage differences in 2011 (compare Table 1). However, we also perform an analysis using Saxonia, Saxonia-Anhalt, and Thuringia as treatment states for agriculture, with similar results.

We measure our outcome variables as the logarithm of the number of apprenticeship contracts in the sector, state, age group, and school degree cell. X_{rstda} comprises the apprentices' secondary school degree and the cell's share of participants in the vocational preparation programme. To prevent multicollinearity and control for time, sector, and state fixed effects, we refrain from including more control variables in our regression equation.

5.2 Descriptive statistics

Table 2 presents summary statistics for contracts with U-18 and O-18 apprentices in treated and non-treated states before and after the minimum wage increase. Our sample comprises 637,226 apprenticeship contracts, resulting in 7,574 observations across aggregation units. The sample sectors cover approximately 12.7% of all the apprentices regulated by the VET and Craft Trade Act in 2019.

Before the minimum wage increase, the treatment states show a higher share of apprentices with a lower school degree compared with control states, which is attributable to characteristics of the school system in Bavaria, one of the largest states with treatment in horticulture, gastronomy, and hospitality, but also to the sector composition in our sample. Between 2008 and 2019, the share of all contracts held by apprentices with a lower school degree is 27.6%, while this share amounts to 35.6% in the sample sectors. The comparison between U-18 and O-18 apprentices shows that the share of separations and participation in vocational preparation programmes is higher among O-18 than among U-18 apprentices. The latter partly explains their older age at the beginning of apprenticeships.

Table 2: Summary Statistics of the aggregated estimation sample

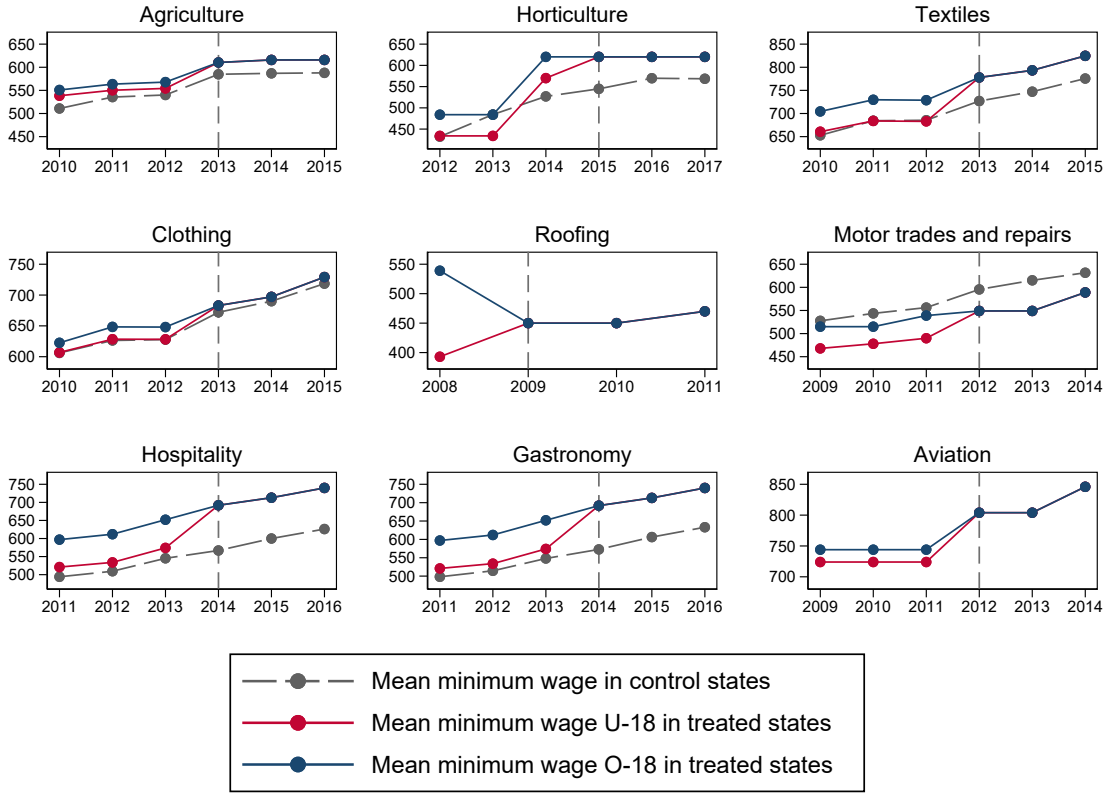
	U-18 apprentices (aged <18)				O-18 apprentices (aged >= 18)			
	Treated		Control		Treated		Control	
	Before	After	Before	After	Before	After	Before	After
Number of contracts	23,358	38,175	74,617	104,428	32,180	61,824	140,646	161,998
Number of obs.	282	889	1,033	1,332	320	1,007	1,224	1,487
Tenure	4.678 [0.322]	4.675 [0.383]	4.529 [0.356]	4.511 [0.348]	5.198 [0.396]	5.131 [0.427]	5.136 [0.425]	5.118 [0.478]
Share separations	0.136 [0.076]	0.124 [0.078]	0.130 [0.086]	0.119 [0.075]	0.246 [0.106]	0.259 [0.092]	0.291 [0.103]	0.285 [0.095]
Female	0.355 [0.244]	0.168 [0.223]	0.325 [0.220]	0.218 [0.191]	0.321 [0.214]	0.153 [0.177]	0.401 [0.174]	0.286 [0.163]
Average minimum wage	510.183 [56.814]	631.723 [101.582]	518.639 [84.026]	653.351 [88.690]	565.377 [51.741]	626.758 [99.577]	505.982 [78.782]	646.228 [84.175]
Lower school degree	0.566 [0.496]	0.501 [0.500]	0.440 [0.497]	0.407 [0.491]	0.504 [0.501]	0.509 [0.500]	0.424 [0.494]	0.407 [0.492]
Preparation programme participants	0.022 [0.034]	0.034 [0.052]	0.037 [0.045]	0.035 [0.045]	0.097 [0.090]	0.116 [0.084]	0.097 [0.070]	0.099 [0.081]

Notes: Means over apprenticeships in the first-year from 2008 to 2019, standard deviations in square brackets. Regarding agriculture, Saxonia, Saxonia-Anhalt, Thuringia, Bavaria, and Hesse are excluded. We exclude inter-company programmes, part-time programmes, contracts with graduates from high school and foreign schools, and implausibly shortened contracts. To calculate the share of separations within the first year of apprenticeship, we consider terminations in the subsequent calendar year and therefore exclude 2019 in this case. Weighted numbers by size of state, sector, year, school degree, and age cell.
Source: VET-Statistics of the Federal Statistical Office and the Federal Statistical Offices of the Länder with survey date 31st December, Registry of Collective Agreements of the Federal Ministry of Labour and Social Affairs.

To provide a comprehensive understanding of the minimum wage adjustments, we plot the first-year minimum wages of apprentices in the nine sample sectors over time (Figure 1). The dashed vertical line indicates the year in which the minimum wage increased for U-18 apprentices. From that year onwards, the mean minimum wages of U-18 apprentices (red line) and O-18 apprentices (blue line) are equal. Minimum

wage profiles of apprentices in non-treated states are represented by the grey, dashed line.[17] The graph highlights two main implications of the analysis. First, the abolition of age-discriminatory minimum wage regulations resulted in an upward adjustment of the U-18 minimum wage to the O-18 minimum wage in all sectors apart from roofing, where both minimum wages move towards one another. Second, the graph shows that except for the year of minimum wage adjustment, the bargained minimum wage of O-18 apprentices in treated states and the apprentice minimum wage in non-treated states mainly move parallel to the U-18 minimum wage. This indicates that there are no structural remuneration-specific differences between U-18 apprentices in treated states and O-18 apprentices in treated states as well as apprentices in non-treated states.

Figure 1: Average minimum wage profiles (in Euro) in treatment and control states over time



Notes: The dashed vertical lines indicate the year of minimum wage increase for O-18 apprentices. See the notes in Table 2 for details on sample composition.
Source: Registry of Collective Agreements of the Federal Ministry of Labour and Social Affairs.

The minimum wage differences between the U-18 and O-18 apprentices vary significantly among the nine sectors. Table 3 shows the effective difference in bargained

[17] As the minimum wage discrimination existed Germany-wide in roofing and aviation, there are no blue lines for those two sectors.

Table 3: Difference in minimum wages for U-18 apprentices in the first year of their apprenticeship in Euro (1) and in % of the O-18 minimum wage (2)

	Difference in Euro (1)	Difference in % (2)
Agriculture		
Schleswig Holstein	10	1.78
Baden-Wurttemberg	27	4.58
Horticulture		
Bavaria	50	8.06
Textiles		
Hesse	46	6.23
Rhineland Palatinate	46	6.23
Saarland	42	6.71
Clothing		
Hesse	25	3.78
Baden-Wurttemberg	18	2.78
Saarland	44	6.78
Roofing		
Germany	146	27.09
Motor trades and repairs		
Northrhine Westphalia	47	9.13
Hospitality and Gastronomy		
Bavaria	78	11.96
Aviation		
Germany	20	2.69

Notes: The numbers represent the difference in the bargained minimum wages between U-18 and O-18 apprenticeships in Euro (1) and as a percentage of the O-18 minimum wage (2) in the year before the abolition.
Source: Registry of Collective Agreements of the Federal Ministry of Labour and Social Affairs

minimum wages between the two groups in their first year in the treated states. The difference is expressed in Euro (1) and as a percentage of the O-18 minimum wage (2) before the abolition. The monthly minimum wage difference varies between 10 Euro/1.78% in agriculture in Schleswig Holstein to 156 Euro/27.09% in roofing. The minimum wage difference is similar across Hesse, Rhineland Palatinate, and Saarland for textiles. In clothing, however, it is nearly twice as large in Saarland compared with the other treated states, and for agriculture, Baden-Wuerttemberg shows a minimum wage difference of more than double the amount of Schleswig Holstein. The weighted average minimum wage difference is 11.28%.

Before presenting the estimation results, we also examine the development of apprenticeship contracts over time. Figure 2 plots the number of U-18 (red line) and O-18 (blue line) apprenticeship contracts in treated states in the nine sample sectors between 2008 and 2019. The dashed vertical line indicates the year in which the minimum wage increased for U-18 apprentices.[18] For agriculture, horticulture, hospitality, and gastronomy, both U-18 and O-18 contracts generally decrease, whereas U-18 contracts decrease to a larger extent. Regarding textiles and clothing, U-18 contracts decrease, while O-18 contracts increase. Roofing and motor trades and repairs show an increasing trend. However, in the latter case, the increase is more apparent among the U-18 contracts. Apprenticeship contracts in aviation are volatile, increasing until 2012 and decreasing thereafter until 2019.[19]

Overall, except for agriculture, motor trades, and repairs and roofing, U-18 and O-18 contracts seem to diverge after the increase in U-18 minimum wages while U-18 contracts mostly (relatively) decrease. The development of apprenticeship contracts over time indicates that U-18 contracts decrease relative to O-18 contracts in adopting states owing to the increased minimum wage for U-18 apprentices.

6 Results

The first panel of Table 4 presents the estimation results for the apprenticeship contracts according to Equation 2. We depict the estimation results for the entire sample in the first column, and the results by school degree in the second and third column. Full regression outputs on employment effects are displayed in Table B.6.

We find an overall effect of -0.214, which is statistically different from zero. The coefficient implies that the minimum wage increase results in a 21.4% decline in U-18 contracts relative to O-18 apprenticeship contracts. Furthermore, we find that the relative decrease in U-18 contracts in the entire sample is driven by a relative decrease of 37.2% among apprentices holding at most lower school degree.[20] For reference, we also provide estimation results not accounting for staggered treatment timing. Implementing Equation 1 yields an ATT of more than twice the size and thus leads to an overestimation of the ATT (compare Table B.1 and B.5).

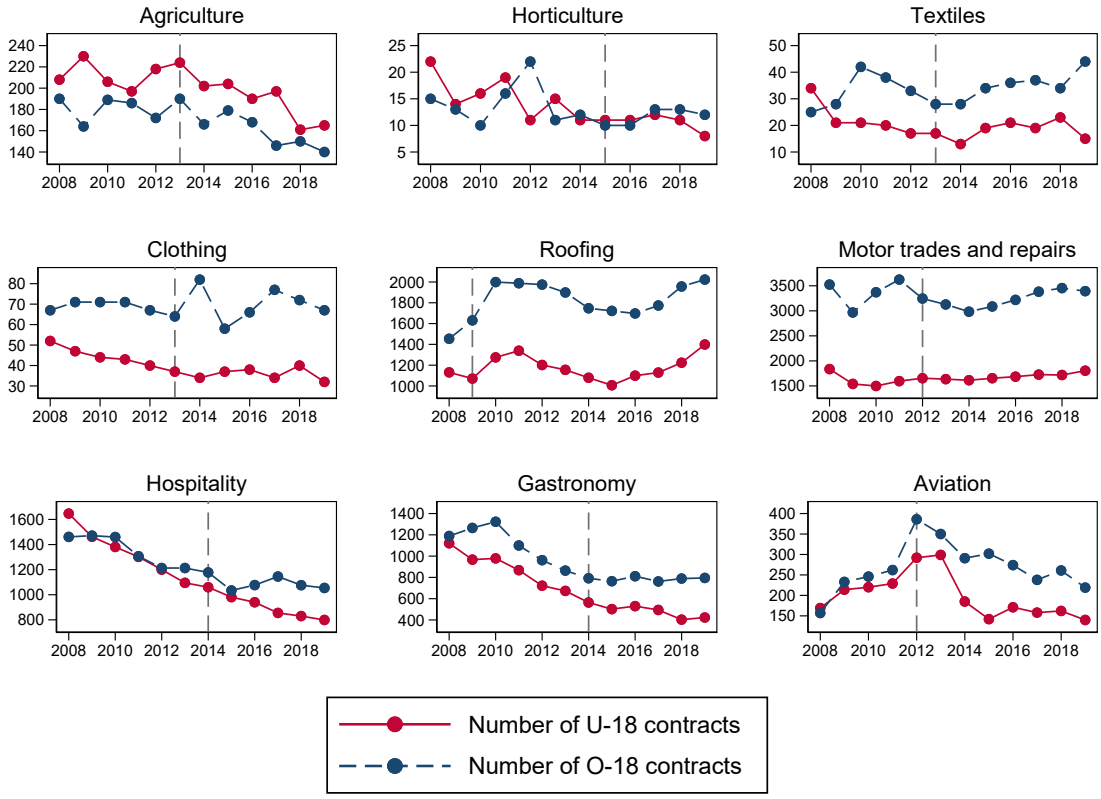
Table 4 also shows the effect of the minimum wage increase on the separation rate in apprenticeships (second panel). Given the small and insignificant coefficient for the incidence of separation in apprenticeships, we find no general evidence that higher

[18] Corresponding numbers of apprenticeship contracts in control states are depicted in A.3.

[19] This is rooted in a market change of the in-house low-cost airlines resulting in an increased fleet and therefore increased personnel requirements up to 2012.

[20] Using the related imputation estimator by Borusyak et al. (2022), as recently applied in von Bismarck-Osten et al. (2022) yields comparable results.

Figure 2: Number of apprenticeship contracts among U-18 and O-18 apprentices in treated states over time



Notes: The dashed vertical lines indicate the year of minimum wage increase for U-18 apprentices. See the notes in Table 2 for details on sample composition.
Source: VET-Statistics of the Federal Statistical Office and the Federal Statistical Offices of the Länder with survey date 31st December.

minimum wages may impede dropping out of apprentices.

Overall, the results support the hypothesis developed in this study that increasing the negotiated minimum wage for underage apprentices has a significant and negative impact on their employment. The respective estimates are substantial in size and are driven by a decrease in apprentices with no or a low schooling degree.

6.1 Heterogeneous effects considering firms' training incentive

The firms' dominating training incentive (the investment or substitution orientation) may notably determine the employment effects in response to a higher apprentice minimum wage (see Section 3.2). Therefore, we analyse the effects on U-18 contracts in relation to the training incentive. To approximate the dominant training incentives of firms in the sample sectors, we follow Mohrenweiser and Backes-Gellner (2010). The authors relate the training incentive to the share of retained apprentices within a firm, where a

Table 4: DDD estimation results using a 2-stage estimator

	Entire Sample	Subsample Analysis	
		no or lower school degree	middle school degree
Number of contracts (log)			
ATT	-0.214**	-0.371***	0.084
	(0.102)	(0.128)	(0.167)
N	7,574	4,648	2,926
Share of separations			
ATT	-0.006	-0.003	-0.008
	(0.009)	(0.010)	(0.012)
N	6,941	4,252	2,689

Notes: Weighted GMM estimation results using 2-step estimator by Gardner (2021), Equation 2. The model includes all control variables that are mentioned in Equation 1. Robust standard errors in parentheses are clustered by state and sector. To calculate the share of separations, we exclude 2019, the last year. See the notes in Table 2 for details on sample composition and weighting. Significance levels are * p<0.1, ** p<0.05, *** p<0.01.
Source: VET-Statistics of the Federal Statistical Office and the Federal Statistical Offices of the Länder with survey date 31st December, Registry of Collective Agreements of the Federal Ministry of Labour and Social Affairs.

high retention rate indicates an investment incentive, and a low retention rate indicates a substitution incentive for training. As a second indication of the training incentive, we compare training costs across sectors, where high costs signal an investment and low (or negative) costs signal a substitution-oriented training strategy.

The first column of Table B.3 shows the ATT of the U-18 minimum wage increase in the six sectors for which data on training incentives are available. We calculate the net firm-level training costs (column 2) and the retention share of apprentices after three (five) years in column 3 (column 4), using the Cost-Benefit Survey 2012/13 (CBS 12/13).[21] All sample sectors, except for motor trades and repairs, have below-average training costs and retention rates. This suggests that horticulture, agriculture, hospitality, gastronomy, and roofing are sectors with a high share of firms pursuing a substitution-oriented training strategy. Firms in the motor trade sector and repairs tend to follow an investment incentive to training based on their above-average training costs and retention rates.

Relating the respective training incentive to employment effects suggests that negative employment effects are larger in sectors in which firms usually train with a substitution-oriented incentive. Motor trade and repairs shows the smallest employment effects. This

[21]The data source and the calculation model used to determine the net training costs are explained in Jansen et al. (2015). We assign the occupations in CBS 12/13 to the sectors in the VET Statistics and drop textiles, clothing, and aviation because of too few observations.

Table 5: DDD estimation results by firms' training incentive using a 2-stage estimator

	Entire Sample	Subsample Analysis	
		no or lower school degree	middle school degree
Number of contracts (log)			
Substitution incentive			
ATT	-0.348***	-0.574***	0.113
	(0.119)	(0.181)	(0.151)
N	6,436	3,894	2,542
Investment incentive			
ATT	-0.068**	-0.297***	-0.194
	(0.030)	(0.106)	(0.150)
N	1,138	754	384
Share of separations			
Substitution incentive			
ATT	-0.004	-0.002	-0.002
	(0.007)	(0.010)	(0.007)
N	5,898	3,561	2,337
Investment incentive			
ATT	-0.034***	-0.036***	-0.034***
	(0.002)	(0.004)	(0.003)
N	1,043	691	352

Notes: Weighted GMM estimation results using 2-step estimator by Gardner (2021). The model includes all control variables that are mentioned in Equation 1. According to Table B.3, we assign firms in the sector of motor trades and repairs to an investment-oriented training incentive, while firms in all other sectors follow a substitution incentive. Robust standard errors in parentheses are clustered by state and sector cells. To calculate the share of separations, we exclude 2019, the last year. See the notes in Table 2 for details on sample composition. * p<0.1, ** p<0.05, *** p<0.01.
Source: VET-Statistics of the Federal Statistical Office and the Federal Statistical Offices of the Länder with survey date 31st December, Registry of Collective Agreements of the Federal Ministry of Labour and Social Affairs.

suggests that our overall estimation results mostly apply to the adjustment mechanism of training firms with a substitution-oriented training incentive. These results are summarised in the upper panel of Table 5, which displays the effects on apprenticeship contracts by the respective training incentive. Full regression outputs are displayed in Table B.7.

We additionally consider the effect on turnover as displayed in the lower panel of Table 5. While there is no evidence for an effect on separations in substitution-oriented sectors, we find a significant effect for motor trades and repair (investment-oriented incentive). A point estimate of -3.4%points can be considered moderately high, given the average rate of separations in this sector of 15.16% between 2008 and 2018. Therefore, we conclude that separations seems to be an adjustment channel of moderate size in sectors that are mainly investment-oriented. This effect can result from both apprentices that earn more and whose outside options consequently become less attractive or from firms that hire more selectively in response to the increased U-18 minimum wage.

6.2 Treatment intensity

We further investigate whether employment effects are larger when the increase in the negotiated minimum wage is higher. We estimate level effects by replacing the treatment indicator in Equation 2 with a continuous treatment variable, more precisely, the minimum wage difference between U-18 and O-18 apprentices just before the upward adjustment of the U-18 minimum wage in Euro, as shown in column (1) of Table 3. This is comparable to Dustmann et al. (2022) who investigate the labour market response to the individual bite of exposure to the introduction of the national minimum wage legislation in 2015 at a regional level.

Using the continuous treatment variable, we estimate the overall ATT as well as separate ATTs for sectors with mainly substitution-oriented and investment-oriented firms, respectively (Table 6). A decrease in the minimum wage difference by 10 Euros results in a decrease in U-18 contracts relative to O-18 contracts by 2.5%. Regarding sectors wherein firms tend to follow a substitution-oriented incentive, an increase in the U-18 minimum wage of 10 Euros causes U-18 contracts to decrease by 3.7%. Here, we find that the higher the U-18 minimum wage increase, the larger the negative employment effects' size. The negative effect is driven by apprentices holding at most a lower school degree, analogous to the binary treatment estimation. We cannot find statistically significant effects on motor trades and repairs, which are dominated by firms with an investment incentive to train. Full regression outputs are displayed in Table B.8.

Table 6: DDD estimation results using a 2-stage estimator with a continuous treatment in Euro

	Entire Sample	Subsample Analysis	
		no or lower school degree	middle school degree
Number of contracts (log)			
All sample sectors			
ATT	-0.003*	-0.003*	-0.000
	(0.001)	(0.002)	(0.003)
N	7,574	4,648	2,926
Substitution incentive			
ATT	-0.004***	-0.006***	0.000
	(0.001)	(0.002)	(0.002)
N	6,436	3,894	2,542
Investment incentive			
ATT	0.001	0.001	0.003
	(0.002)	(0.004)	(0.005)
N	1,138	754	384

Notes: Weighted GMM estimation results using the 2-step estimator by Gardner (2021) with a continuous treatment variable (the minimum wage difference between U-18 and O-18 apprentices in Euro just before U-18 minimum wage adjustment). The model includes all control variables that are mentioned in Equation 1. According to Table B.3, we assign firms in the sector of motor trades and repairs to an investment-oriented training incentive while firms in all other sectors follow a substitution incentive. Robust standard errors in parentheses are clustered by state and sector. See the notes in Table 2 for details on sample composition. * $p<0.1$, ** $p<0.05$, *** $p<0.01$.
Source: VET-Statistics of the Federal Statistical Office and the Federal Statistical Offices of the Länder with survey date 31st December, Registry of Collective Agreements of the Federal Ministry of Labour and Social Affairs.

6.3 Timing of effects

To address the potential issue of anticipation effects, we include the leading values of the treatment indicators in our regression analysis. By including lagged values, we examine whether the estimated treatment effect varies over time (phase-in effects) as it splits the average effect of the ATT across different time periods (see, for example, Kurtz et al., 2020; Cengiz et al., 2019 for comparable applications). To extend the two-stage estimation described in Equation 2 to an event study setting, Equation 3 regresses the residuals of the first stage on the two treatment indicators; however, replacing $post_t$ in the second stage with $\mathbb{1}\{k = t - E_i\}$, where T_r is the time when the minimum wage increases for apprentices in sector r and $\mathbb{1}\{k = t - T_r\}$ indicates the kth period until or after the minimum wage increases. $k = -1$ represents the year before the policy change (Lead 1), and $k = 2$ indicates the third period after the policy change (Lag 2). We express the estimates as changes from reference year $k = -1$. To prevent multicollinearity, we include two lags and leads (cf. Schmidheiny and Siegloch, 2019).

$$\begin{aligned} E_{rstda} =& \alpha + \beta_1 X_{rstda} + \beta_2 \tau_t + \beta_3 \gamma_s + \beta_4 \lambda_r + \beta_5 \text{U18}_a \\ &+ \beta_8 \text{treated}_s \times \text{U18}_a + \epsilon_{rstda}. \end{aligned} \tag{3a}$$

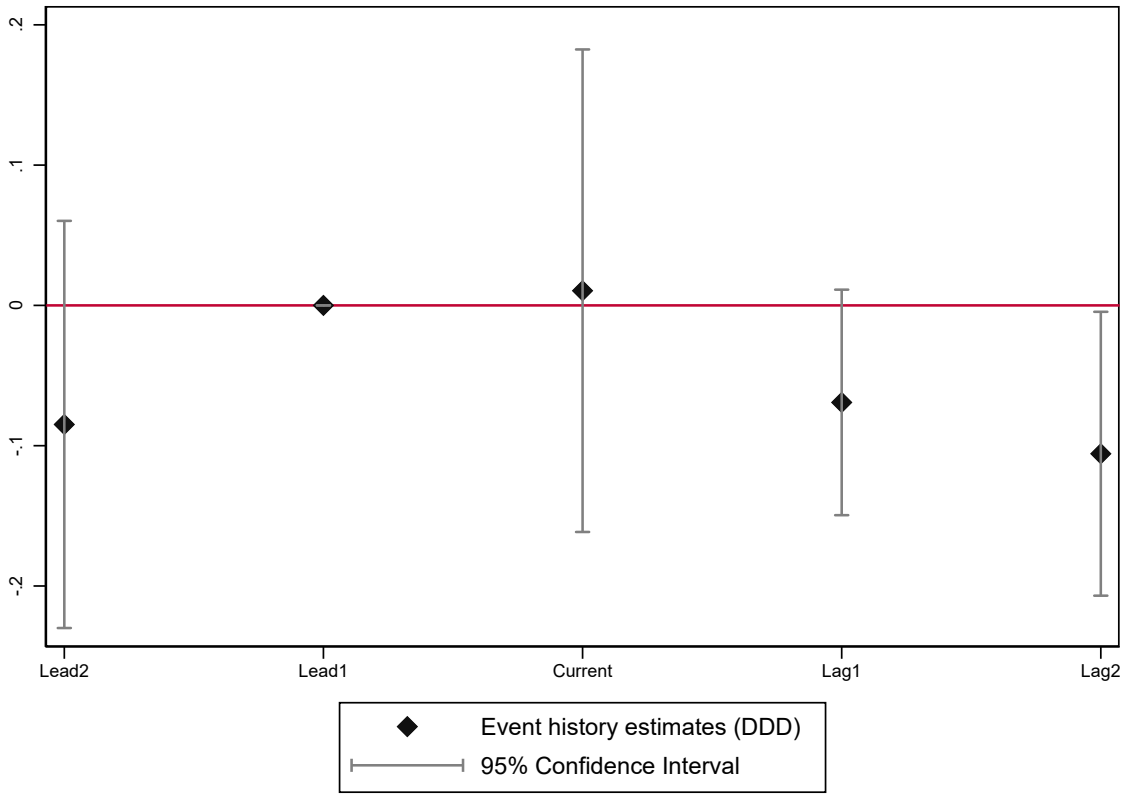
$$\begin{aligned} \widetilde{E}_{rstda} =& \delta + \sum_{k=-2}^{2} \theta_{1,k} \mathbb{1}\{k = t - T_r\} \times \text{treated}_s \\ &+ \sum_{k=-2}^{2} \theta_{2,k} \mathbb{1}\{k = t - T_r\} \times \text{treated}_s \times \text{U18}_a + \eta_{rstda} \end{aligned} \tag{3b}$$

Figure 3 reports the coefficient estimates of $\theta_{2,k}$, indicating the effect of the treatment on U-18 apprentices in period k. Lead 2 does not differ significantly from zero. Therefore, we find no evidence for anticipatory effects. These lagged values suggest that the negative employment effect increases over time. This lends support to the hypothesis that it takes some adjustment time for firms to react to the increased minimum wage (Meer and West, 2016).

6.4 Robustness analysis

We further explore the robustness of the benchmark model (Equation 2) to several variations in sample selection (Table B.4). First, we repeat our analyses, excluding roofing and aviation, as these are the only two sectors with nationwide collective agreements (Model 1). Second, we run regressions excluding the small states of Berlin, Bremen, Hamburg, and Saarland, which have comparably low numbers of apprenticeship contracts (Model 2). In both specifications, estimated effects are very similar to those

Figure 3: Event study analysis using a 2-stage estimator after Gardner (2021)



Notes: The Figure plots the GMM estimates of $\theta_{2,k}$ of Equation 3 with 95% confidence intervals. Lead2 = 1 if the wage increase occurs two years in the future. The year before the wage increase (Lead 1) is the reference group. The model includes all control variables that are mentioned in Equation 1. Compare the notes in Table 2 for details on sample composition.
Source: VET-Statistics of the Federal Statistical Office and the Federal Statistical Offices of the Länder with survey date 31st December, Registry of Collective Agreements of the Federal Ministry of Labour and Social Affairs.

in our baseline specification.

Third, we test for the robustness of our results taking account of a supply shock that occurred in Germany between the years 2007 and 2013. In selected years and states, double cohorts entered the training market owing to a high school reform,[22] which increased the number of apprenticeship contracts of high school graduates (Muehlemann et al., 2022). Although Muehlemann et al. (2022) show that school graduates with lower-level qualifications were not affected by the reform, we also control for the number of U-18 high school graduates in the federal states using data from the Federal Statistical Office (Model 3). Our results remain robust.

[22]The G8 high school reform in Germany reduced the minimum duration to obtain a high school degree (Abitur) from 9 to 8 years of secondary schooling, which led to two graduation cohorts in a specific year and state.

Fourth, we rule out that the decreasing number of U-18 apprenticeship contracts in treated states is attributable to a lower supply of applying school graduates in certain sample occupations. Therefore, Table A.5 outlines the number of registered unsuccessful apprenticeship applicants in the treated states by sector. The numbers show that the excess supply of apprenticeship applicants actually increased over time in many sectors, and motor trades and repairs, textiles, clothing, and agriculture seem to have become more attractive occupations for youths, while we note only small decreases in the sectors of hospitality and gastronomy in Bavaria. Hence, there is no reason to suspect that the results are driven by a lack of apprenticeship applicants.

Finally, national minimum wage legislation was introduced in Germany in 2015 and partly replaced sector-specific minimum wages for skilled workers. Recent literature suggests that this may also have affected the apprenticeship market. Schumann (2017) finds negative employment effects for apprentices in the construction sector following the introduction of the minimum wage in 2015 in the main construction sub-sectors in Germany in 1997. Moreover, Anger et al. (2021) find evidence for a higher tendency of youths to pursue higher school degrees instead of apprenticeships following the introduction of the national minimum wage in 2015. In our sample, roofing is the only sector with a sector-specific minimum wage since 1997. However, it only required small adjustments to meet new minimum wage requirements.[23] In our estimations, year-fixed effects capture the possible effects of the introduction of the national wage legislation in 2015. However, including these did not significantly alter the results. Overall, the analysis above shows that our results are robust to different specifications and samples.

7 Conclusion

This study analyses the impact of raising negotiated minimum wages on the employment of young apprentices in Germany. Exploiting exogenous staggered wage increases for underage apprentices, we find a large and significantly negative employment effect for the group of treated apprentices. The effect is driven by a reduction in the apprenticeship contracts for low-qualified apprentices. Overall, we do not find any support for a separation-reducing effect of the minimum wage increase. Merely in sectors, where firms train with an investment incentive, the minimum wage adjustments moderately reduce the rate of apprentices not completing their training programme.

The findings of this study contribute to the minimum wage literature by providing so far lacking evidence for the impact of increasing minimum wages in apprenticeship

[23] See `https://www.lohn-info.de/mindestlohn_dachdeckerhandwerk.html`.

markets. As the majority of the sectors affected by the negotiated minimum wage increases are characterised by a highly competitive environment with mainly small and substitution-oriented firms, we expected that a raise in minimum wages negatively impacts the number of hired apprentices. While the evidence for minimum wage effects in the literature is ambiguous concerning "regular" labour markets, our study suggests that the substantial increase in the minimum wage in the German training market came at the cost of lower employment of the affected group.

The results are therefore also of relevance for policy makers, who face the decision of implementing or expanding already existing minimum wage legislation for apprentices. As Manning (2021) points out, international organisations such as OECD and ILO recommend the implementation of minimum wages to ensure that work is rewarding to all (OECD, 2018).

However, apprenticeships are a special case. In Germany, they provide the majority of non-college bound youth with marketable skills and a nationally recognised occupational degree. Considering that young workers without a qualification face higher risks of unemployment and lower wages in the future (Wolter and Ryan, 2011), apprenticeships are of immense importance for a successful transition from education to the labour market. Increasing firms' training wages (and therefore the training costs) for minor apprentices leads to the rational decision of not providing training slots, and thus to a limitation of transition options especially for youth with no or low schooling degrees.

References

Acemoglu, D., Pischke, J.S., 1999a. Beyond Becker: Training in imperfect labour markets. The Economic Journal 109 (453), 112–142.

Acemoglu, D., Pischke, J.S., 1999b. The structure of wages and investment in general training. Journal of Political Economy 107 (3), 539–572.

Adema, J., Giesing, Y., Schoenauer, A., Stitteneder, T., 2019. Minimum wages across countries. ifo DICE Report 16 (4), 55–63.

Allegretto, S., Dube, A., Reich, M., 2017. Credible Research Designs for Minimum Wage Studies: A Response to Neumark, Salas, and Wascher. ILR Review 70 (3), 559–592.

Anger, S., Hess, P., Kunaschk, M., 2021. Minimum Wages and Teenagers' Educational Plans, In: Essays in Applied Labor Economics (Doctorial dissertation of Kunaschk, M.). Friedrich-Alexander-Universitaet Erlangen-Nuernberg, Nuernberg. Available from `https://opus4.kobv.de/opus4-fau/frontdoor/index/index/year/2021/docId/16846`.

Behling, R., Speckesser, S., 2013. An impact analysis of the introduction of the Apprentice Rate of the National Minimum Wage. Institute for Employment Studies, Brighton.

Beicht U., Walden, G., 2012. Ausbildungsverguetungen in Deutschland als Ausbildungsbeihilfe oder Arbeitsentgelt. WSI-Mitteilungen 5/2012, 338–349.

Berck, P., Villas-Boas, S.B., 2016. A note on the triple difference in economic models. Applied Economics Letters 23 (4), 239–242.

Boeri, T., van Ours, J., 2013. Minimum Wages, In: The Economics of Imperfect Labor Markets, 2. Princeton University Press, Oxford, pp. 35–62.

Borusyak, K., Jaravel, X., Spiess, J., 2022. Revisiting event study designs: Robust and efficient estimation. Available at SSRN: `https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2826228`.

Bossler, M., Gerner, H.D., 2020. Effects of the New German Minimum Wage: Evidence from Establishment-Level Microdata. ILR Review 73 (5), 1070–1094.

Callaway, B., Sant'Anna, P., 2021. Difference-in-differences with multiple time periods. Journal of Econometrics 225 (2), 200–230.

Card, D., Krueger, A.B., 1994. Minimum Wages and Employment: A Case Study of the Fast-Food Industry in New Jersey and Pennsylvania. The American Economic Review 84 (4), 772–793.

Cengiz, D., Dube, A., Lindner, A., Zipperer, B., 2019. The effect of minimum wages on low-wage jobs. The Quarterly Journal of Economics 134 (3), 1405–1454.

Croucher, R., White, G., 2011. The impact of minimum wages on the youth labour market: An international literature review for the Low Pay Commission. Middlesex University Research Repository, London.

de Linde Leonard, M., Stanley, T.D., Doucouliagos, H., 2014. Does the UK Minimum Wage Reduce Employment? A Meta-Regression Analysis. British Journal of Industrial Relations 52 (3), 499–520.

Deutscher Bundestag, 2019. Entwurf eines Gesetzes zur Modernisierung und Staerkung der beruflichen Bildung. Gesetzentwurf der Bundesregierung, Drucksache 19/10815.

Doucouliagos, H., Stanley, T.D., 2009. Publication Selection Bias in Minimum-Wage Research? A Meta-Regression Analysis. British Journal of Industrial Relations 47 (2), 406–428.

Dube, A., Lester, W., Reich, M., 2016. Minimum wage shocks, employment flows and labor market frictions. Journal of Labor Economics 34 (3), 663–704.

Dustmann, C., Schoenberg, U., 2012. What Makes Firm-Based Vocational Training Schemes Successful? The Role of Commitment. American Economic Journal: Applied Economics 4 (2), 36–61.

Dustmann, C., Lindner, A., Schoenberg, U., Umkehrer, M., vom Berge, P., 2022. Reallocation Effects of the Minimum Wage. The Quarterly Journal of Economics 137 (1), 267–328.

Ellguth, P., Kohaut, S., 2021. Tarifbindung und betriebliche Interessenvertretung: Aktuelle Ergebnisse aus dem IAB-Betriebspanel 2020. WSI-Mitteilungen 04/2021, 306–314.

Ellis, C.M., Grace, M.F., Smith, R.A., Zhang, J., 2022. Medical cannabis and automobile accidents: Evidence from auto insurance. Health Economics 31 (9), 1878–1897.

Federal Statistical Office, 2020. Subject-matter Series 11, Part 1. Federal Statistical Office of Germany, Wiesbaden. Available from `https://www.statistischebibliothek.de/mir/receive/DESerie_mods_00000110`.

Gardner, J., 2021. Two-Stage Difference-in-Differences. Boston College Working Paper, Available from https://bit.ly/3AF32Af.

Giuliano, L., 2013. Minimum Wage Effects on Employment, Substitution, and the Teenage Labor Supply: Evidence from Personnel Data. Journal of Labor Economics 31 (1), 155–194.

Heidorn, H., Weche, J., 2020. Business Concentration Data for Germany. Jahrbücher für Nationalökonomie und Statistik 241 (5-6), 801–811.

Hirsch, B.T., Kaufman, B.E., Zelenska, T., 2015. Minimum Wage Channels of Adjustment. Industrial Relations 54 (2), 199–239.

Hirschman, A.O., 1964. The paternity of an index. The American Economic Review 54 (5), 761–762.

Hyslop, D., Stillman, S., 2007. Youth minimum wage reform and the labour market in New Zealand. Labour Economics, 14 (2) 201–230.

Hyslop, D., Stillman, S., 2021. The Impact of the 2008 Youth Minimum Wage Reform in New Zealand. Series of Unsurprising Results in Economics No. 5, Canterbury. Available from https://ir.canterbury.ac.nz/handle/10092/101808.

Jaeger, S., Noy, S., Schoefer, B., 2022. The German Model of Industrial Relations: Balancing Flexibility and Collective Action. Journal of Economic Perspectives 36 (4), 53–80.

Jansen, A., Pfeifer, H., Schoenfeld, G., Wenzelmann, F., 2015. Apprenticeship training in Germany remains investment-focused – results of BIBB Cost-Benefit Survey 2012/13. BIBB report 1/15, Bonn. Available from https://www.bibb.de/en/25852.php.

Kocher, E., 2015. Das Allgemeine Gleichbehandlungsgesetz (AGG) in der Tarifpolitik: Tarifpolitische Handlungshilfe zum AGG für TarifverhandlerInnen und Mitglieder von Tarifkommissionen. Hans-Boeckler-Stiftung, Berlin/Frankfurt(Oder).

Kreiner, C.T., Reck, D., Skov R.E., 2020. Do lower Minimum Wages for Young Workers Raise their Employment? Evidence from a Danish Discontinuity. The Review of Economics and Statistics 102 (2), 339–354.

Kurtz, M.D., Smith Conway, K., Mohr, R.D., 2020. Weekend feeding ("BackPack") programs and student outcomes. Economics of Education Review 79, 102040.

Lindley, R.M., 1975. The Demand for Apprentice Recruits by the Engineering Industry: 1951-1971. Scottish Journal of Political Economy 22, 1–24.

Manning, A., 2021. The Elusive Employment Effect of the Minimum Wage. Journal of Economic Perspectives 35 (1), 3–26.

Manning, A., 2003. The real thin theory: monopsony in modern labour markets. Labour Economics 10 (2), 105–131.

Meer, J., West, J., 2016. Effects of the Minimum Wage on Employment Dynamics. Journal of Human Resources 51 (2), 500–522.

Mohrenweiser, J., Backes-Gellner, U., 2010. Apprenticeship Training: for Investment or Substitution? International Journal of Manpower 31 (5), 545–562.

Monopolies Commission, 2020. Competition 2020. Biennial Report XXIII, Bonn.

Muehlemann, S., 2016. The Cost and Benefits of Work-based Learning. OECD Education Working Papers 143, OECD Publishing, Paris.

Muehlemann, S., Pfeifer, H., Walden, G., Wenzelmann, F., Wolter, S., 2010. The financing of apprenticeship training in the light of labor market regulations. Labour Economics 17 (5), 799–809.

Muehlemann, S., Ryan, P., Wolter, S., 2013. Monopsony Power, Pay Structure and Training. ILR Review 66 (5), 1097–1114.

Muehlemann, S., Dietrich, H., Pfann, G., Pfeifer, H., 2022. Supply Shocks in the Market for Apprenticeship Training. Economics of Education Review 86, 102197.

Mann, S., 2021. Transgender employment and gender marker laws. Labour Economics 73, 102072.

Neumark, D., Wascher, W., 2004. Minimum wages, labor market institutions, and youth employment: A cross-national analysis. ILR Review 57 (2), 223–248.

Olden, A., Møen, J., 2022. The Triple Difference Estimator. The Econometrics Journal 25 (3), 531–553. Available from `https://doi.org/10.1093/ectj/utac010`.

Organisation for Economic Cooperation and Development (OECD): 2018. Good Jobs for All in a Changing World of Work: The OECD Jobs Strategy. OECD Publishing, Paris. Available from `https://doi.org/10.1787/9789264308817-en`.

Papps K.L., 2020. How the Minimum Wage Affects Training among Apprentices. IZA Discussion Paper No. 13499, IZA, Bonn.

Ryan, P., 2016. Monopsony Power and Work-based Training, In: Coppola, G., O'Higgins, S.N. (Eds.), Youth and the crisis: Unemployment, education and health in Europe. Routledge Studies in Labour Economics, Routledge, London, pp. 13–35.

Schmidheiny, K., Siegloch, S., 2020. Event Study Designs and Distributed-Lag Models: Equivalence, Generalization and Practical Implications. CESifo Working Paper No. 7481, Available at SSRN: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3338836.

Schoenfeld, G., Wenzelmann, F., Pfeifer, H., Risius, P., Wehner, C., 2020. Training in Germany – an investment to counter the skilled worker shortage. Results of the 2017/18 BIBB Cost-Benefit Survey. BIBB report 3, Bonn. Available from https://www.bibb.de/dienst/publikationen/de/16745.

Schumann M., 2017. The effects of minimum wages on firm-financed apprenticeship training. Labour Economics 47, 163–181.

Uhly, A., 2022. Erlaeuterungen zum Datensystem Auszubildende (DAZUBI) Auszubildenden-Daten, Berufsmerkmale, Berechnungen des BIBB. Federal Institute for Vocational Training and Education, Bonn. Available from https://www.bibb.de/dokumente/pdf/dazubi_daten.pdf.

Verdi, 2007. Tarifpolitik und Allgemeines Gleichbehandlungsgesetz. ver.di – vereinte Dienstleistungsgewerkschaft, Berlin. Available from https://frauen.verdi.de/themen2/nachrichten/++co++03b28014-1a02-11e3-bb00-525400438ccf.

von Bismarck-Osten, C., Borusyak, K., Schoenberg, U., 2022. The role of schools in transmission of the SARS-CoV-2 virus: quasi-experimental evidence from Germany. Economic Policy 37 (109), 87–130.

Wenzelmann, F., Schoenfeld, G., 2020. BIBB-Datenbank Tarifliche Ausbildungsvergütungen - Methodische Hinweise zur Revision der Berechnungsweise. Bundesinstitut für Berufsbildung, Bonn. Available from https://www.bibb.de/dokumente/ablage/TariflicheAV_Methodik_final_NEU_mit_Cove.pdf.

Wolter, S.C., Ryan, P., 2011. Apprenticeship, In: Hanushek, E.A., Woessmann, L. (Eds.), Handbook of the Economics of Education, 3. Elsevier, Chapter 11, pp. 521–576.

Wooldridge, J., 2021. Two-Way Fixed Effects, the Two-Way Mundlak Regression, and Difference-in-Differences Estimators. Available at SSRN: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3906345.

Appendix

A Figures

Figure A.1: Minimum wages in a competitive and monopsonistic apprenticeship market

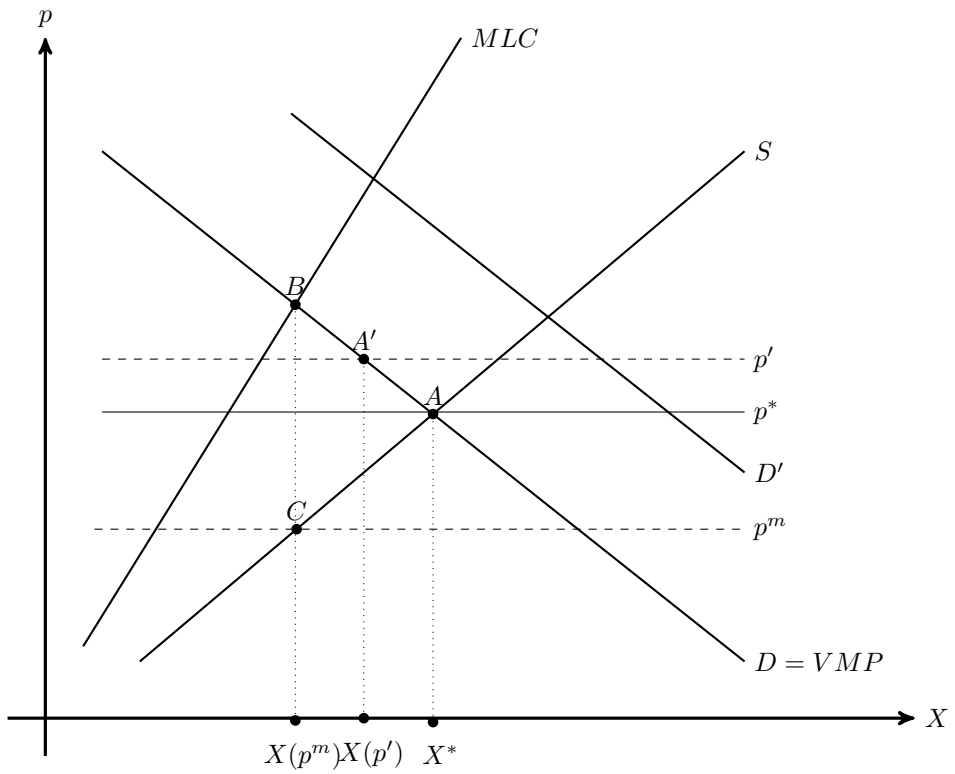
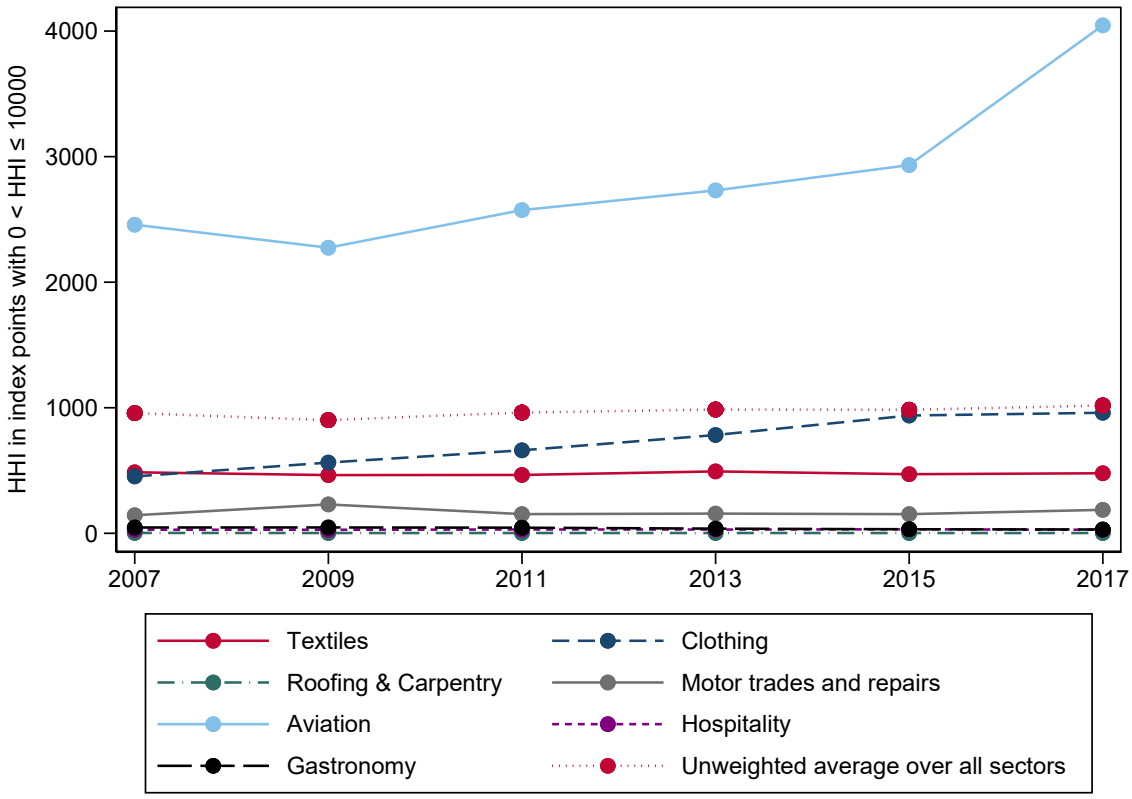


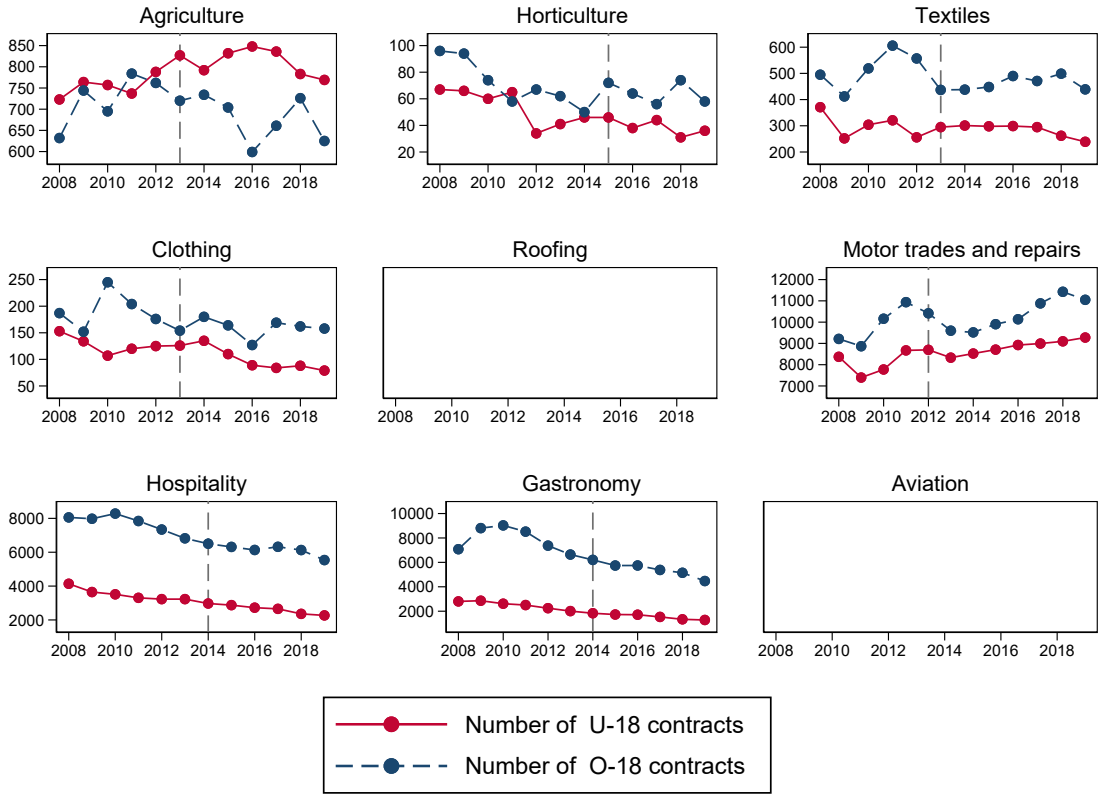
Figure A.1 depicts the number of apprenticeship contracts X in relation to the apprentice wage level p. A minimum wage p' above the competitive equilibrium A resulting in (X^*,p^*) leads to an excess supply of apprentices with fewer hired apprentices ($X(p')$). A monopsonist, however, faces an upward-sloping supply curve (MLC) as the wage increase of hiring an additional apprentice has to be granted to all apprentices in the workforce. The profit-maximising choice is ($X(p^m)$,p^m), with fewer apprentices at a lower wage compared with the competitive equilibrium. An increase in the minimum wage between p^m and p^* is determined by the respective level on the apprentice supply curve S, whereas an increase above p^* is determined by the respective level on the demand curve D. A minimum wage above B results in an apprenticeship level is even lower than the monopsonistic equilibrium (Boeri and Urs, 2013). Thus, the degree of monopsony power (BC) may be a factor determining the direction of employment effects in response to minimum wage increases.
Additional monopsony power in the market for skilled workers, shown by the demand curve D' that is shifted to the right, results in an equilibrium with more apprentices and a higher wage compared to the case of pure monopsony power over apprentices. A high monopsony power over skilled workers relative to the monopsony power over apprentices can thus lead to an equilibrium that is close to the competitive equilibrium (Muehlemann, 2016; Muehlemann et al., 2013). A modest wage increase (below the intersection of MLC and the demand curve) though generally results in fewer apprentices at a lower wage level.

Figure A.2: Degree of revenue concentration measured by the sector-specific Herfindahl-Hirschman Index (HHI) between 2007 and 2017



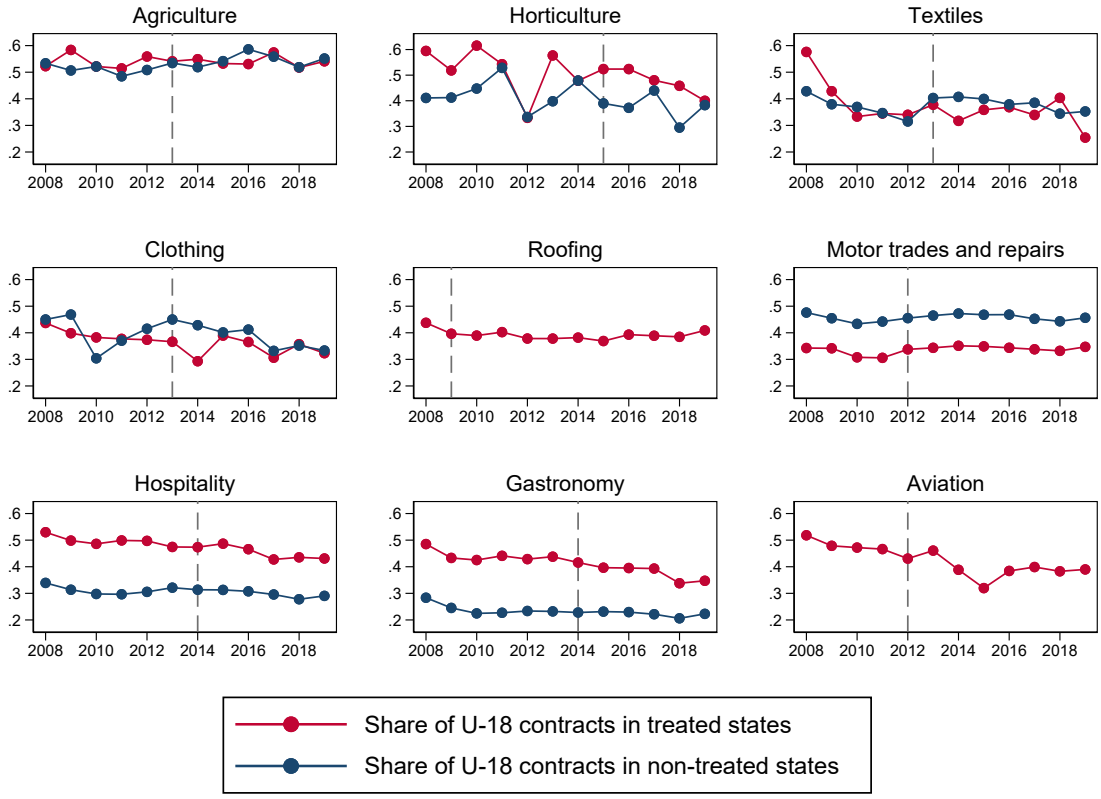
Notes: The HHI is defined as the sum of the square of the revenue shares of all suppliers in a market and can reach values between 0 and 10,000. Markets with low HHI values are considered unconcentrated markets with high competition, where many firms of more or less equal size share the market. As a rough guidline, the EU Merger Control classifies HHI values between 1,000 and 2,000 as harmless (Monopolies Commission, 2020). We use a panel for the period 2007–2017 at a biannual interval with HHIs and overall revenues at a 4-digit industry level. For Textiles, Clothing, Motor trades and repairs, Hospitality, and Gastronomy, the indices are averages weighted by the respective revenue shares. The large increase in revenue concentration in Aviation in 2017 is attributable to the insolvency of AirBerlin in 2017 (Monopolies Commission, 2020). The unweighted median over the years 2007-2017 is 486.64. Source: Business Concentration Data provided by the German Monopolies Commission based on German business register data of the Federal Statistical Office. Compare Heidorn and Weche (2021) for a data manual.

Figure A.3: Number of apprenticeship contracts of U-18 and O-18 apprentices in control states over time



Notes: The dashed vertical lines indicate the year of minimum wage increase for U-18 apprentices in treated states. Compare the notes in Table 2 for details on sample composition.
Source: VET-Statistics of the Federal Statistical Office and the Federal Statistical Offices of the Länder with survey date 31st December.

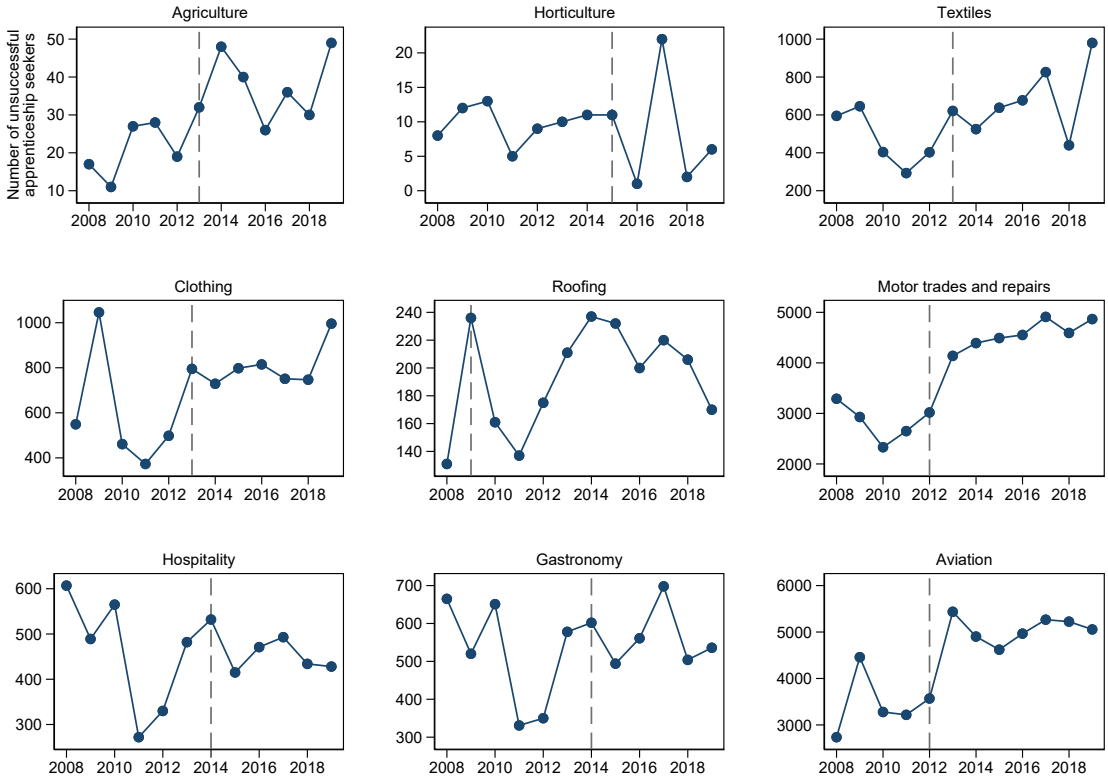
Figure A.4: Share of U-18 apprenticeship contracts in treatment and control states by sector



Notes: Weighted values, only including contracts with apprentices in their first year. The depicted shares of U-18 contracts in treated shares are not statistically different from respective shares in control states except for textiles in 2008 ($p<0.05$).

Source: VET-Statistics of the Federal Statistical Office and the Federal Statistical Offices of the Länder with survey date 31st December.

Figure A.5: Number of unsuccessful apprenticeship seekers in treated states by sector



Notes: Unsuccessful apprenticeship seekers who are registered at the BA matched to sectors and states by occupation and federal state.
Source: VET-Statistics of the Federal Statistical Office and the Federal Statistical Offices of the Länder with survey date 31st December, BIBB Statistics with survey date 30th September.

B Tables

Table B.1: DDD estimation results using standard approach

	Entire Sample	Subsample Analysis	
		no or lower school degree	middle school degree
Number of contracts (log)			
ATT	-0.509***	-0.544***	-0.332***
	(0.148)	(0.175)	(0.083)
N	7,574	4,648	2,926
Share of separations			
ATT	-0.006	-0.010	-0.005
	(0.010)	(0.009)	(0.010)
N	6,941	4,252	2,689

Notes: Weighted OLS Regression results of Equation 1 on log VET contracts. The ATT is β_9 of Equation 1. The model includes all control variables that are mentioned in Equation 1. Robust standard errors in parentheses are clustered by state and sector. To calculate the share of separations, we exclude 2019, the last year. See the notes in Table 2 for the sample composition, weighting and data source. Significance levels are * p<0.1, ** p<0.05, *** p<0.01.
Source: VET-Statistics of the Federal Statistical Office and the Federal Statistical Offices of the Länder with survey date 31st December, Registry of Collective Agreements of the Federal Ministry of Labour and Social Affairs.

Table B.2: Overview of the composition of firms in the sample sectors by size in % over time

	2005	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Agriculture													
less than 10 ha				24.6			23.5			23.5			
[10 - 50 ha[				46.8			46.2			45.5			
[50 - 200 ha[				25.0			26.2			26.5			
[200 - 1000 ha[				3.1			3.5			4.0			
1000 and more ha				0.5			0.5			0.6			
Horticulture													
less than 1 ha	47.3									40.3			
[1 - 5 ha[	29.8									30.9			
[5 - 20 ha[	15.9									19.1			
20 and more ha	6.9									9.7			
Textiles													
less than 50 empl.		44.8	47.9	44.7	45.5	46.7	47.0	46.8	46.9	45.1	44.2	46.3	46.6
50-99 empl.		26.7	25.8	28.6	28.1	26.9	25.9	25.5	26.0	26.2	26.8	24.7	23.8
100-499 empl.		27.1	25.3	25.4	24.9	25.1	25.8	26.7	26.0	27.6	27.9	27.9	28.6
500 and more		1.4	1.0	1.4	1.5	1.4	1.3	1.0	1.1	1.1	1.1	1.1	1.0
Clothing													
less than 50 empl.		48.8	50.4	46.7	44.6	46.5	45.4	45.2	47.6	46.8	46.6	45.7	45.9
50-99 empl.		26.0	24.9	27.9	29.2	27.9	27.1	25.0	23.2	24.2	23.5	21.4	20.7
100-499 empl.		22.6	21.8	22.3	23.0	22.3	24.3	26.5	25.1	25.0	26.7	29.1	29.3
500 and more		2.6	2.8	3.1	3.3	3.3	3.2	3.3	4.1	4.0	3.2	3.8	4.1
Roofing													
less than 10 empl.		81.7	81.5	80.6	79.6	80.5	79.9	78.4	78.4	79.1	79.4	78.9	78.7
10-19 empl.		14.0	13.9	14.4	15.3	14.5	14.7	16.1	16.0	15.2	14.9	15.3	15.3
20-49 empl.		3.9	4.1	4.5	4.7	4.5	4.8	5.0	5.1	5.1	5.1	5.2	5.4
50 and more		0.5	0.5	0.4	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6

Continued on next page

Table B.2 – continued from previous page

	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Motor trades and repairs													
less than 10 empl.		76.8	77.0	77.1	77.1	77.4	77.4	76.8	76.9	77.1	76.9	76.5	76.5
10-19 empl.		12.9	13.0	12.9	12.9	12.6	12.6	13.2	13.2	12.8	12.8	13.0	12.9
20-49 empl.		7.4	7.3	7.2	7.2	7.2	7.1	7.1	7.1	7.1	7.2	7.4	7.4
50 and more		2.9	2.8	2.8	2.9	2.8	2.8	2.8	2.8	3.0	3.1	3.2	3.2
Hospitality and gastronomy													
less than 10 empl.		81.2	78.9	78.0	76.7	76.6	76.2	75.0	74.2	72.2	72.2	71.5	72.2
10-49 empl.		17.4	19.1	20.0	21.4	21.3	21.8	22.9	23.5	25.2	25.4	25.7	25.1
50- 249 empl.		1.3	1.9	1.8	1.8	2.0	1.9	2.0	2.1	2.5	2.3	2.7	2.6
250 and more		0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Source: Federal Statistical Office. Note that numbers for motor trades and repairs and roofing refer to craft companies ("Handwerksunternehmen"), comprising all establishments of the company. The shares of the other sectors comprise establishments.

Table B.3: Relation between employment effects and sector-specific VET characteristics

	ATT on contracts (log)	**Firm-level net training costs**	**Share of apprentices staying within the firm**	
			after 3 years	after 5 years
Horticulture/ Gardening	-0.378***	-706	31.034	25.618
	(0.021)	[6044.069]	[32.423]	[29.256]
N	454	41	40	40
Agriculture	-0.408**	-15	16.345	13.945
	(0.173)	[6149.093]	[28.960]	[26.433]
N	600	76	72	72
Hospitality and Gastronomy	-0.336***	4,074	20.121	10.168
	(0.088)	[7010.596]	[32.970]	[24.661]
N	2,243	189	174	168
Roofing	-0.724***	4,455	19.383	13.093
	(0.233)	[6495.285]	[31.242]	[26.522]
N	1,088	26	23	23
All sectors		5,635	39.523	30.158
		[8676.499]	[40.582]	[37.418]
N		3,032	2,771	2,690
Motor trades and repairs	-0.068**	6,156	43.557	34.861
	(0.030)	[8365.704]	[42.873]	[41.955]
N	1,138	137	125	122

Notes: Employment effects in column 1 are weighted GMM estimation results using 2-step estimator by Gardner (2021) at the sector level. Robust standard errors in parentheses are clustered by state and sector. Mean net firm-level training costs and retention share depicted in columns 3-5 with standard deviations in square brackets. The model includes all control variables that are mentioned in Equation 1. Compare the notes in Table 2 for the sample composition, weighting and data source. * p<0.1, ** p<0.05, *** p<0.01.
Source: VET-Statistics of the Federal Statistical Office and the Federal Statistical Offices of the Länder with survey date 31st December, Registry of Collective Agreements of the Federal Ministry of Labour and Social Affairs, BIBB-CBS 2012/2013.

Table B.4: Robustness Checks

Model specification/Outcome	Entire Sample	Subsample Analysis	
		no or lower school degree	middle school degree
Number of contracts (log)			
(1) Excluding sectors without control states			
ATT	-0.210***	-0.384***	0.118
	(0.067)	(0.073)	(0.176)
N	5,720	3,528	2,192
(2) Excluding small federal states			
ATT	-0.222**	-0.359***	0.099
	(0.103)	(0.121)	(0.181)
N	5,989	3,701	2,288
(3) Controlling for high-school graduates			
ATT	-0.215**	-0.348***	0.082
	(0.101)	(0.116)	(0.167)
N	7,574	4,648	2,926

Notes: Weighted GMM estimation results using 2-step estimator by Gardner (2021) and the basic control variables that are mentioned in Equation 1. Model (1) without Roofing and Aviation, Model (2) without Berlin, Hamburg, Bremen, and Saarland, and Model (3) including the numbers of U-18 high school graduates. Cluster-robust standard errors by state and sector in parentheses. See the notes in Table 2 for details on the sample composition. * p<0.1, ** p<0.05, *** p<0.01.
Source: VET-Statistics of the Federal Statistical Office and the Federal Statistical Offices of the Länder with survey date 31st December, Registry of Collective Agreements.

Table B.5: Full DDD regression results using a standard approach

	Entire Sample	Subsample Analysis	
		no or lower school degree	middle school degree
Dep. Variable: Number of contracts			
Treatment indicators			
Treated*post*U-18	-0.509***	-0.544***	-0.332***
	(0.148)	(0.175)	(0.083)
Treated*U-18	-0.319	-0.356	-0.228
	(0.241)	(0.306)	(0.147)
Treated*Post	0.224	0.239	0.091
	(0.194)	(0.252)	(0.160)
Post*U-18	0.246***	0.144***	0.322***
	(0.051)	(0.051)	(0.062)
Treatment dummy	-0.614***	-0.567***	0.044
	(0.135)	(0.184)	(0.148)
Covariates			
Lower school degree	2.195***	2.204***	–
	(0.071)	(0.064)	
Middle school degree	2.294***	–	–
	(0.092)		
Participants in preparation programme	-0.690*	-0.305	-0.401
	(0.351)	(0.350)	(0.639)
Fixed effects			
Sector FE	yes	yes	yes
Federal State FE	yes	yes	yes
Year FE	yes	yes	yes
Constant	2.097***	2.149***	4.244***
	(0.287)	(0.316)	(0.237)
N	7,574	4,648	2,926

Notes: Weighted OLS Regression results of Equation 1. Robust standard errors in parentheses are clustered by state and sector. See the notes in Table 2 for details on sample composition. * p<0.1, ** p<0.05, *** p<0.01.
Source: VET-Statistics of the Federal Statistical Office and the Federal Statistical Offices of the Länder with survey date 31st December, Registry of Collective Agreements.

Table B.6: Full DDD estimation results using a 2-stage estimator with a binary treatment variable

	Entire Sample	Subsample Analysis	
		no or lower school degree	middle school degree
Dep. Variable: Number of contracts			
Treatment indicators (second stage)			
Treated*post*U-18	-0.214**	-0.347***	0.084
	(0.102)	(0.116)	(0.167)
Treated*Post	-0.024	-0.033	-0.026
	(0.071)	(0.059)	(0.142)
Treatment indicators (first stage)			
Treated*U-18	0.184	0.187	0.114
	(0.225)	(0.295)	(0.289)
Treatment dummy	-0.334**	-0.220	0.222
	(0.149)	(0.220)	(0.211)
Covariates			
Lower school degree	2.418***	2.282***	–
	(0.077)	(0.058)	
Middle school degree	2.615***	–	–
	(0.119)		
Participants in preparation programme	1.481**	1.895***	11.819***
	(0.616)	(0.601)	(2.806)
Fixed effects			
Sector FE	yes	yes	yes
Federal State FE	yes	yes	yes
Year FE	yes	yes	yes
Constant	0.038	0.025**	0.037
	(0.015)	(0.012)	(0.023)
N	7,574	4,648	2,926

Notes: Weighted GMM estimation results using 2-step estimator by Gardner (2021), Equation 2. Robust standard errors in parentheses are clustered by state and sector. See the notes in Table 2 for details on sample composition. * p<0.1, ** p<0.05, *** p<0.01. Source: VET-Statistics of the Federal Statistical Office and the Federal Statistical Offices of the Länder with survey date 31st December, Registry of Collective Agreements.

Table B.7: Full DDD estimation results by firms' training incentive using a 2-stage estimator with a binary treatment variable

	Substitution incentive	Investment incentive
Dep. Variable: Number of contracts		
Treatment indicators (second stage)		
Treated*post*U-18	-0.348***	-0.068**
	(0.119)	(0.030)
Treated*Post	-0.016	0.013
	(0.045)	(0.032)
Treatment indicators (first stage)		
Treated*U-18	0.686***	-0.481**
	(0.161)	(0.215)
Treatment dummy	-0.557***	0.529**
	(0.093)	(0.265)
Covariates		
Lower school degree	2.384***	3.931***
	(0.105)	(0.380)
Middle school degree	2.523***	3.186***
	(0.141)	(0.233)
Participants in	2.160***	6.549***
preparation programme	(0.756)	(1.586)
Fixed effects		
Sector FE	yes	–
Federal State FE	yes	yes
Year FE	yes	yes
Constant	0.009	-0.023
	(0.010)	(0.024)
N	6,436	1,138

Notes: Weighted GMM estimation results using 2-step estimator by Gardner (2021), Equation 2. According to Table B.3, we assign firms in the sector of motor trades and repairs to an investment-oriented training incentive, while firms in all other sectors follow a substitution incentive. Robust standard errors in parentheses are clustered by state and sector. See the notes in Table 2 for details on sample composition. * p<0.1, ** p<0.05, *** p<0.01.
Source: VET-Statistics of the Federal Statistical Office and the Federal Statistical Offices of the Länder with survey date 31st December, Registry of Collective Agreements.

Table B.8: Full DDD estimation results using a 2-stage estimator with a continuous treatment in Euro

	Entire Sample	Subsample Analysis	
		no or lower school degree	middle school degree
Dep. Variable: Number of contracts			
Treatment indicators (second stage)			
Treated*post*wagedifference	-0.003*	-0.003*	0.000
	(0.001)	(0.002)	(0.003)
Treated*Post	0.030	-0.011	0.045
	(0.079)	(0.073)	(0.172)
Treatment indicator (first stage)			
Wagedifference	-0.001	0.000	-0.001
	(0.002)	(0.002)	(0.002)
Covariates			
Lower school degree	2.388***	2.272***	–
	(0.080)	(0.060)	
Middle school degree	2.599***	–	–
	(0.112)		
Participants in preparation programme	1.707***	1.940***	7.285***
	(0.519)	(0.573)	(1.752)
Fixed effects			
Sector FE	yes	yes	yes
Federal State FE	yes	yes	yes
Year FE	yes	yes	yes
Constant	-0.021	-0.012	0.039
	(0.027)	(0.036)	(0.038)
N	7,574	4,648	2,926

Notes: Weighted GMM estimation results using 2-step estimator by Gardner (2021), Equation 2 with a continuous treatment variable (the minimum wage difference between U-18 and O-18 apprentices in Euro just before U-18 minimum wage adjustment). Robust standard errors in parentheses are clustered by state and sector. See the notes in Table 2 for details on sample composition. * p<0.1, ** p<0.05, *** p<0.01.
Source: VET-Statistics of the Federal Statistical Office and the Federal Statistical Offices of the Länder with survey date 31st December, Registry of Collective Agreements.